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CONTENT Page

A Study of the Wear Resistance of Weld Overlay Coatings Produced By Using Flux Shielding In an Abrasive Environment

Ognyan Slivarov, Iliya Todorov, Gergana Staneva

Abstract: *The article studies the wear resistance of weld overlaid coatings produced by using flux shielding of components from agricultural, transport, construction and forestry machinery which are used in an abrasive environment. The obtained results reveal that the coatings obtained through weld overlaying with DUR 600 electrode wire and FBTT flux possess the highest wear resistance in a dry and wet abrasive environment. The gradual change in the magnitude of wear of these coatings allows for the prediction of changes in the technical condition of restored components.*

Keywords*: abrasive wear, submerged arc welding and overlaying*

INTRODUCTION

Wear resistance of restored components of contemporary agricultural, transport, forestry and construction machinery is largely determined by their wear resistance in an actual working environment. This type of equipment functions in abrasive environments, which accelerate considerably the wear of machine components. With reference to this, the aim of researchers and technical experts is to reduce components' wear and increase durability of machinery.

Increasing the wear resistance of agricultural, transport, forestry and construction machinery components after repairs is achieved through weld overlaying of wear resistant layers on worn components. One of the main methods for restoring running gear components of tracked machines is weld overlaying using flux shielding. The occurrence, development and intensity of the wear process are determined by the properties of the restorative coatings, their quality and the external conditions and influences.

The purpose of this article is to determine the wear resistance of large – sized components of tracked tractors, which were restored by flux - shielded weld overlaying and which work in an abrasive environment.

MATERIAL AND METHODS

The methodology for the study of wear resistance of flux - shielded weld overlay coatings was developed according to current understanding of scientific research in this field [3, 7].

The input factors of the cybernetic research model are as follows: **Tp** is the vector of the abrasive media's parameters (type and condition of the abrasive media; interaction of the abrasive media and the sample); **Pp** is the vector of the friction mode (weight/force applied, velocity of movement, temperature mode, length of experiments, etc.) and **Kp** is the vector of the coating's parameters (type of the coating and its quality characteristics) (see Fig. 1).

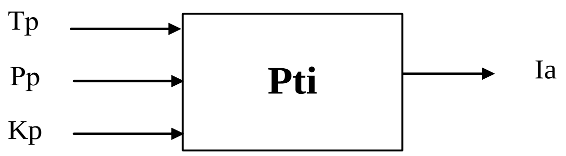

Fig. 1 Model for testing friction and wear in an abrasion - free environment:
Tp – vector of the abrasive environment's parameters; Pp – vector of the friction mode;
Kp – vector of the coating's parameters; Ia – vector of the samples' wear.

The output parameter, characterizing the process of friction and wear of samples in an abrasive environment, is the vector of abrasive wear of the samples obtained during laboratory testing **Ia** (size, dynamics, intensity of wear and wear resistance).

The methodology for studying the wear resistance of weld overlaid coatings uses the CT - 1 stand for friction and wear in a free abrasive environment, which was specially designed and produced by our research team . The stand permits the wearing of the friction surface during sliding.

When selecting the abrasive environment, we followed the principle of achieving maximum similarity between laboratory and real conditions of friction and wear. For the tests we used abrasive material molding mixture type K16 with grain size of 0,016 mm. Molding mixture type K16 is used in metal casting for molds. With its specifications, this molding mixture is very close to the environment in which agricultural, transport, construction and forestry machinery functions.

The study was conducted at two moisture levels of the abrasive environment, i.e. “dry” (with moisture W 10% of the moisture holding capacity limit) and “wet” (with moisture W 90% of the moisture holding capacity limit). The hydro-abrasive environment is obtained by using a special attachment to the CT – 1 device for tribological wear. To achieve the constant moisture level of the abrasive environment, we pour water in a special tank. The water flows with particular water flow to the abrasive environment. The level of abrasive dust before the test must cover the samples, mounted on the disk.

The scheme of interaction between the test sample and the abrasive environment, reproduced by the CT – 1 device, could feature lower and upper abrasive. Under the “lower abrasive” test scheme, force is applied between the samples and the abrasive environment. This is accompanied by intensive friction, higher degrees of wear and overall heating of the work environment. Under the “upper abrasive” test scheme, the samples raise the abrasive mixture, which is under them. The applied force and the resulting friction and wear are considerably lower.

The choice of a particular test scheme depends on the conditions in which the tested components function and has to recreate these conditions as closely as possible. The test for determining the wear resistance of flux – shielded weld overlay coatings was conducted by using the “lower abrasive” test scheme. According to this scheme the samples are flat and cleaned after being treated

The rotational speed of the samples is 80 min^{-1}. It is a constant value and does not change during the experiment. The rotational radius of the samples is 120 mm. The temperature of the process during the tests corresponds to the temperature of the natural environment. The samples are mounted on the disk at an angle of 30°, to permit intensive friction between the abrasive and the tested sample. The feeding of the dust abrasive as well as the mounting and dismounting of the disk is done by removing the cover.

With reference to chosen methodology, the overall tests length in an environment, made up of the type K16 molding mixture, was 48 hours (2880 min). These minutes were distributed in 6 experiments of 8 hours (480 min) for the samples in each group. When the overall duration expires, the abrasive environment is replaced with a new one. The number of experiments is determined by the requirements of mathematical statistics and the theory of probability.

Based on the modal and average values of the statistical distribution of the worn components, for the experiment we selected the “model” component, which corresponds to the agricultural and transport machinery components. A considerable number of the oversized components, subjected to abrasive wear, rotate. Therefore, for the purposes of the study the weld overlaid samples used were also rotating.

Table 1 *Parameters of the multilayer weld overlay mode of the rotating samples*

Indicators	Value
Arc voltage, V Of the first layer Of the second layer	 33 28
Magnitude of current, A	180-200
Type of current	Direct
Weld overlay speed, m\min	1,26
Spacing between weld overlay seams, mm\ min-1 Of the first layer Of the second layer	 3 3
Speed of feeding the electrode wire, m\min Of the first layer Of the second layer	 0,9 0,9
Diameter of the electrode wire, mm	1,2
Stick – out of the electrode wire, mm	15
Total thickness of the weld overlay layer, mm	3,6 – 6,8

The selected "model" has the following characteristics: material – St 45, hardness of the base metal – 200-220 HB, diameter - 100 mm, length - 200 mm and weight - 12 kg, thickness of weld overlaid coating - 10 mm [5, 6]. The coating is produced by weld overlaying with an intermediary layer due to its better formation properties and the need of smaller amounts of filler metal for further mechanical treatment [2]. The parameters of the flux shielded weld overlay process are outlined in Table 1.

The samples used are cut from the weld overlaid components and these samples are used for the study of friction and wear in an abrasive environment. The parameters of the samples are as follows: length L = 50 mm, width B = 35 mm, thickness b = 5 mm, weight of the base G = 70-80 g [1].

The running gear components of tracked machines function in conditions causing heavy abrasive wear which is also accompanied by considerable shock loads. These components can be considerably worn. However, this can be compensated by the weld overlaying of several layers of seams. The last layer must be wear resistant while the intermediary ones have other functions.

In addition, multilayer weld overlaying is a suitable solution because the last layer can be made by using an expensive, wear resistant, filler material, which meets the requirements for reliability of the restored components, while the other layers could function as a base. To a great extent, these requirements can also be met by applying several layers of the same filler material because the last layer contains a smaller amount of the base material and a bigger amount of the filler material, which increases the hardness of the coating. When the first layer is applied, the hard alloy is inevitably mixed with the base metal of the component and its amount is bigger than that of the alloy. Therefore, the wear resistance and hardness of the first weld overlaid layer are lower. The percentage of the hard alloy increases with the application of the other layers.

Multilayer weld overlaying helps to reduce the cooling rate of the weld overlaid surface. It is recommended that each successive layer is applied before the restored component is completely cooled. What is more, the lower layer is reheated by the upper layer. As a result, the ductility and toughness of the multilayer seams are increased. Another advantage of multilayer weld overlaying is that the evenness of the coating increases with each successive layer deposited.

The studied weld overlay coatings are obtained by flux shielded, multilayer weld overlaying on rotating components. The coatings consist of two layers made of identical materials and fluxes (table 2). The weld overlay samples are organized in groups according to the filler material and flux used. In each group there are six samples.

The selected electrode wires refer to the stainless and heat resistant steels. Their chemical composition of these wires is close to that of the base metal used for the production of most of the oversized components. The filler material has a diameter of 1,2 mm. The selected protective OK 1096 flux, produced by ESAB, has good metallurgical properties. The CS 350 and FBTT fluxes have good alloy properties with reference to improving the wear resistance of weld - overlaid working surfaces.

***Table 2** Materials used for the flux – shielded multilayer weld overlaying of the rotating samples*

№	Electrode material	Flux
1	Sv 08G2S	CS 350
2	Sv 08G2S	OK 1096
3	Np 30HGSA	FBTT
4	Np 18 HGSA	FBTT

The wear magnitude of the weld overlaid coatings is determined by measuring the samples weight at the beginning and end of each experiment with an accuracy of 0,1 mg by using an analytical balance, type WA 33 PRLTA 13/1. The changes in the samples' weight at the end of each experiment provide data for preparing the dynamics of change in wear resistance in the process of abrasive wear. The wear dynamics and wear intensity of the "standard" sample and the weld - overlaid samples are determined according to the methodology, outlined in ГОСТ 23.208 – 79 [1].

RESULTS AND DISCUSSION

The dynamics of the change in the overall wear magnitude of the "standard" sample and the samples with the restorative coatings is shown on Figures 2 and 3.

The weld – overlaid samples (see Fig.2) have considerably lower wear compared to the wear of the "standard" sample in a dry abrasive environment. For the "standard" sample and all the groups with weld – overlaid samples, there is a considerately gradual and even increase in the loss of material during the experiment. This property is beneficial during exploitation because it does not permit sharp fluctuations in the size of components subjected to wear. This also permits predictions concerning changes in the size of components and the related maintenance and repair activities.

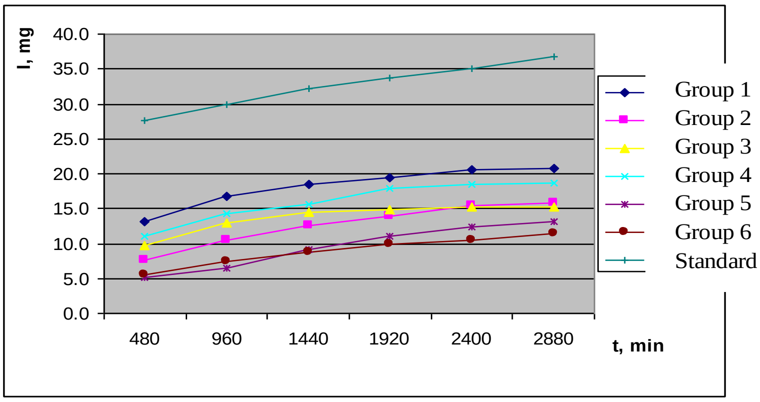

Fig. 2 Dynamics of the wear magnitude of the "standard" sample and the samples with two identical weld overlaid layers in a dry abrasive environment, made of the K16 moulding mixture

According to Fig. 2, the samples from groups 2, 5 and 6 have wear values of 10…15 mg at the end of the experiment while at the end of the cycle the overall lost material is approximately 20 mg for the other samples and 37 mg for the "standard" sample.
The samples from group 1 have the highest overall wear. At the end of the experiment it reaches a value of 20,5 mg. Groups 6 and 5 have the lowest overall wear. It is 11 mg and 13 mg respectively at the end of the cycle. This wear is nearly twice lower, compared to the wear of the samples from group 1. For group 5 the magnitude of wear after the first experiment has increased only by 5 mg.
In the study of wear resistance in a wet abrasive environment, the samples make considerable efforts to overcome the compacted abrasive material compared to the efforts they make in a dry abrasive environment. Therefore, in this case the wear is higher, compared to the one in a dry environment.

The changes in the overall wear in a wet abrasive environment are analogical to the ones in a dry abrasive environment. However, the wet abrasive increases the overall wear of the samples by 2 to 8 mg (see Fig. 3). During the experiment, the samples from groups 2, 5 and 6 have the lowest overall wear values. At the end of the cycle, they are 16 mg, 15,5 mg, and 15 mg respectively.

The samples from groups 1, 3, and 4 have the highest overall wear values in a wet abrasive environment. This trend is identical with the trend, recorded during the experiment in a dry abrasive environment. However, the obtained values are higher.

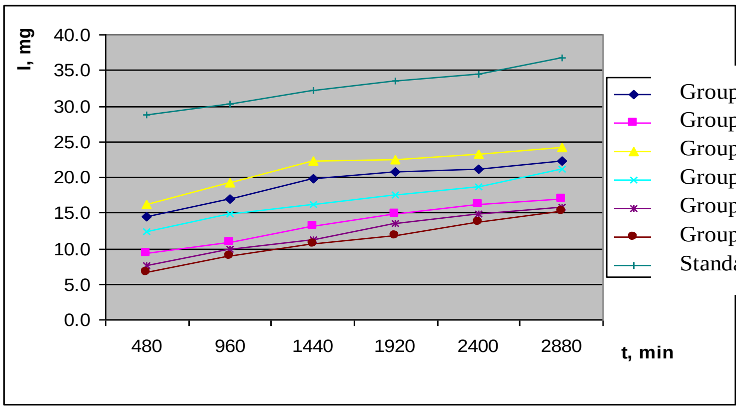

Fig. 3 Dynamics of the wear magnitude of the "standard" sample and the samples with two identical weld overlaid layers in a wet abrasive environment, made of the K16 molding mixture

The wear of the samples from group 6 is the lowest overall wear recorded for the dry and wet abrasive environment. The increase in wear after the first experiment is within the range of 6 cm, which is approximately 30% of the overall sum wear. This gradual increase in wear permits specialists to predict the wear of oversized components and forecast changes in their resources.

***Table 3** Wear resistance and relative wear resistance of samples, weld overlaid with two identical layers*

Samples	Wear resistance		Relative wear resistance	
	Dry	Wet	Dry	Wet
Group 1	0,08	0,07	2	1,75
Group 2	0,12	0,14	3	3,5
Group 3	0,11	0,07	2,75	1,75
Group 4	0,10	0,10	2, 5	2,5
Group 5	0,18	0,16	4,5	4
Group 6	0,18	0,16	4,5	4
Standard	0,04	0,04	1	1

In addition to wear magnitude, the intensity of wear, as one of the main tribological properties, is also of significant importance for assessing the changes in the size of friction surfaces. Intensity of wear permits the comparison of wear of restored components made of different materials. It also provides information about the loss of material with reference to the distance, covered by the studied surface subject to wear, as well as the thickness of the material, used for the production of the same surface. One of the main requirements to the weld overlay material is its sufficient wear resistance under the given working conditions, which are characterized by the wear intensity.

According to Fig. 4, the intensity of wear decreases rapidly during the first 24 hours. After that, it remains nearly constant and on the graphs, there is a smooth transition from the steep to the shallow section of the curve. This can be explained by the lower hardness of moulding mixture type K16. Naturally, the "standard" samples have a higher intensity of wear compared with the test samples.

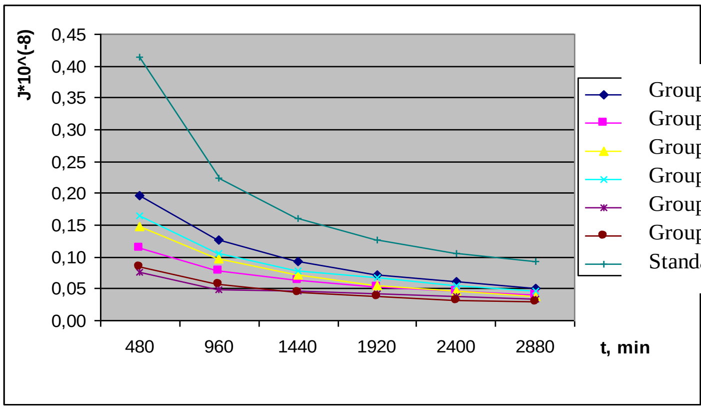

Fig. 4 Wear intensity of the "standard" sample and the samples with two identical weld overlaid layers in a dry abrasive environment, made of the K16 molding mixture

The samples from groups 5 and 6 have the lowest wear intensity (see Fig. 4). The intensity of wear is the highest for groups 1, 3 and 4. This reveals that the restorative coatings from groups 5 and 6 have higher durability.

According to Fig. 5, the intensity of wear of the samples, tested in a wet abrasive environment, is higher than the intensity of wear of the samples tested in a dry abrasive environment. This is also proved by the results in [4]. The samples from groups 5 and 6, tested in an environment made up of moulding mixture type K16, have the lowest intensity of wear compared to the samples from the other groups.

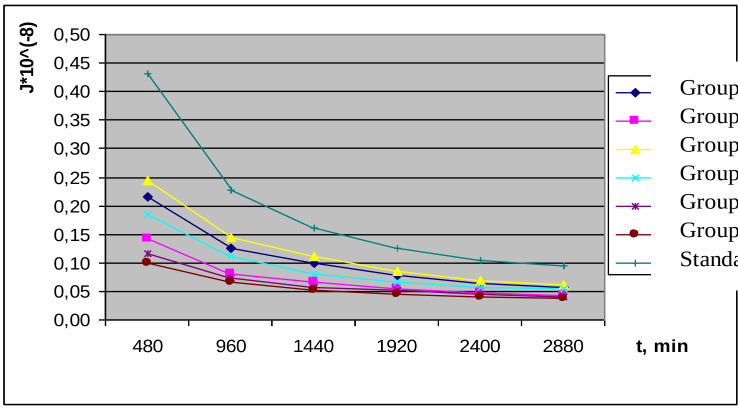

Fig. 5 Wear intensity of the "standard" sample and the samples with two identical weld overlaid layers in a wet abrasive environment, made of the K16 molding mixture

The “standard” samples have the highest intensity of wear in a wet abrasive environment. The samples from groups 1, 3 and 4 have the second highest intensity of wear.

The wear resistance of the oversized components weld overlaid by using flux shielding is a complex property and depends on a number of factors such as the percentage of carbon and alloying elements, the obtained hardened structures, and the toughness and fragility of the weld overlaid metal. By increasing the toughness of the weld overlaid metal we, by rule, increase the wear resistance of the components working in an abrasive environment.

The results concerning the wear resistance and the relative wear resistance of the weld – overlaid samples produced by using flux shielding are shown in Table 3. The relative wear resistance is determined according to the “standard” sample.

The data in Table 3 shows that the weld – overlaid samples from group 5 and 6 have the highest wear resistance in a dry and wet abrasive environments. For the dry abrasive environment the wear resistance is 1,5 times higher compared to the one of the other groups and 2,5 times higher than the wear resistance of the “standard” sample. This is also confirmed by the results for the wear of the samples from this group which are shown on Fig. 2. The weld overlaid coatings from group 1, 3 and 4 have the lowest wear resistance.

The results from the tribological studies of the flux – shielded weld overlaid coatings on running gear components of agricultural, construction and forestry machinery, working in an abrasive environment, show that the lowest wear and the highest wear resistance is recorded for the coatings from group 6.

CONCLUSIONS

1. Restorative coatings are characterized by a gradual increase in overall wear. This allows users to make predictions concerning wear of running gear components from agricultural, transport, construction and forestry machinery, functioning in conditions of abrasive wear. This also permits forecasts concerning the replacement of worn components.
2. At the end of the tests conducted, flux – cored weld overlay coatings, produced with DUR 600 electrode wire and FBTT flux possess the smallest values of overall wear in dry and wet abrasive environments, namely 11 - 15mg.
3. The lowest wear intensity of flux – cored weld overlay coatings is recorded for electrode wires DUR 600 and DUR 500. This proves the high durability of these coatings under conditions of abrasive wear.
4. The highest wear resistance under conditions of abrasive wear in dry and wet environments is possessed by the flux – cored, weld overlay coatings from group 5 and 6.

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Processes of Quality Planning and Quality Assurance in Automotive

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Pavol Findura, Miroslav Pristavka

Abstract: *A part of the systematic approach in project management in automotive industry is a phase described as launch of a product into the serial production. This process is in his development further structured into several sub-processes. One of them are processes of quality planning and quality assurance, which define the frame for fulfill of all requirements on quality of a new product set by the customer according the norm ISO/TS 16949 and VDA2. The main goal of these processes is the approval of a product into the serial production described based on the norm as the PPAP process.*

Keywords: *quality planning, automotive industry, PPAP process*

INTRODUCTION

Part of the systematic approach in the project management by introducing a new product in the automotive industry is the launch of the product in to the serial production. This process is further subdivided into individual subprocesses. One of them is the planning and quality assurance process, that defines the exact framework to meet all of the quality requirements of the new product set by customers in accordance with ISO / TS 16949 and VDA2 standards. The main purpose of these processes is to release parts from the quality perspective in to the serial production according to the standardized steps set out in the PPAP process.

MATRIAL AND METHODS

PROCESSES OF PLANNING AND QUALITY ASSURANCE

The planning and quality assurance processes are one of the main processes of quality management within the project which is in the phase of the launch of product in to the serial production. According to the literature, quality planning defines which quality standards apply to the project and determines how to meet these standards [7]. On the other hand, quality assurance is a regular evaluation of the overall performance of the project in order to provide the confidence, that the project will meet the relevant standards [7].

From customer requirements, an effective quality concept tailored to product and process risk is defined through the quality planning process. This is to evaluate, define and implement a series of optimization and corrective actions affecting product quality that have emerged from the product's production process and mass production. Consequently, in the quality assurance process, security measures are implemented and their effectiveness checked. In automotive industry the planning and quality assurance processes are in the responsibility of the planning department or quality assurance department [2]. For the quality management area in automotive industry, four steps can be identified for the launch of a product in to the serial production:

- - Determining quality requirements from customer requirements
- - Embedding quality requirements into dimensioning and demonstration of feasibility
- - Product and process management in a serial production
- - Optimization and adjustment

Determining quality requirements from customer requirements

The goal of the process of determining quality requirements is to check customer requirements against existing product standards and supplement or update them in case of any differences. This process is running in the product definition phase. The customer requirements defined in the request list need to be checked from a quality point of view and

then compared with existing product standards. After re-checking it is required to give project management a feedback about the result. He checks and then creates a list of product quality specifications.

Embedding quality requirements into dimensioning and prove of feasibility

The goal of the process of incorporating requirements is to ensure the development of a stable product and process up to the phase of design freeze [1]. This process runs through three phases: prototype phase, optimization phase and launch phase.

In the prototype phase, the functionality of the product is developed according to the specification list, focusing on product performance testing [6, 11, 12]. The main task of the process is the detailed risk analysis of the FMEA of the product, referred to as DFMEA. Based on a drawing or request sheet, DFMEA analyses and evaluates potential product risks to determine the specific features of the product. Subsequently, DFMEA will develop measures to reduce the potential risks of the product and these will be recorded in verification plan. Based on DFMEA and planning of the mass production process, a FMEA of the process called PFMEA is created. Specific features are transferred from DFMEA to PFMEA. In order to reduce the potential risks of the process, measures will be created which are summarized in a plan for process and monitored and implemented as part of the process development. At the customer's request, it is possible to create a quality control checklist for prototypes. This contains all the risk signs that are relevant to the product under FMEA.

During the optimization phase quality measures to ensure product and process stability are established and verified. The main task is to optimize the production process for its smooth – rump up. After incorporating a portion of the identified risk measures, DFMEA is upgraded and the product achieves the degree of maturity required for the design freeze (design freeze). Production processes are defined in the manufacturing or process flow diagram. Based on defined serial processes, PFMEA sets out measures to improve and secure processes. To further reduce potential risks in the process, process plan will be created for the optimization phase. Based on the PFMEA, a control plan for a serial process is created, from which the concept of the series of instruments and test equipment is derived. Subsequently, the development and procurement of test facilities can begin.

During the launch phase the measures taken to ensure the quality of the product in the mass production are being implemented. DFMEA and PMFEA should be checked based on the results from the optimization phase tests. After verification, it is possible to close the FMEA process. On the basis of updated FMEA data, the control plan for the mass production is reworked. For the mass production test equipment the capability study needs to be done, of which the result is relevant to the release of the process. It is also necessary to demonstrate machine and process capability study before producing the first serial samples. Subsequently, serial sample documentation according to the PPAP process needs to be prepared.

Product and process management in the mass production

The goal of the production control process is to provide and demonstrate stable repeatability of products produced under serial conditions to match the drawing specifications in the required quantity and time, to meet the quality and cost requirements. This process takes place during the product's launch phase and the type and scope of the control is determined in the test plan for the product for the mass production. When determining the deviation from the required specification, it is necessary to implement the following process control measures, that are defined in the control plan:

– - The process must be stopped and can only be started after the new settings and releases.
– - The non-conformity product management process will start.
– - Product complaint can be initiated

Optimization and modification

The aim of the optimization process is to improve the quality measures in the mass production. Quality planning needs to be optimized towards testing efficiency and production with zero error by feedback from manufacturing tests and input control. All optimization changes need to be reviewed and compared to the drawing specifications and FMEA of the product. If changes are not blocked, it is possible to modify the control plan, process flow chart, and inform the customer (if necessary). Reasons for optimization can be as follows: test plan corrections, failure to achieve capability values, customization of test frequency and real-time measurement techniques, product and process changes.

Production parts approval process (PPAP)

In the automotive industry the process of approving parts into the mass production is referred to the Production Part Approval Process (PPAP). This process ensures that products meet customer quality requirements, with emphasis on product and process control [4, 10]. The release process itself involves product release through sample and process control through product or process audit checkings to ensure that products meet all the requirements. In the automotive industry, the PPAP process monitors the execution of all activities within the launch of a new or changed product and process under the ISO / TS 16949 standard as well as other VDA 6, QS9000, EAQF 94 and AVSQ 94 by submitting documents such as e.g. DFMEA, PFMEA, process flow chart, control plan, process capability test results, and Part Submission Warrant PSW. Submission of the necessary documents is divided according to the submission stages in ISO / TS 16949 [Annex 1]. In connection with the release of samples, process audits are also carried out according to the standards mentioned [3, 8, 9].

Product release

Product release samples are product samples, for which compliance with specified requirements can be verified, as specified in the drawing. The first serial samples are parts produced with serial equipment and under serial conditions. Serial equipment means serial tools, machines and production lines. Serial conditions represent serial production and control processes. Deliveries to the customer can only be started after successful release of the first samples. The first serial samples must be submitted in the following cases:

- - the start of a new part or product that has not yet been delivered to the customer
- - design changes with effects on drawing specifications or product material
- - removing the part error that has already been delivered to the customer with a conditional release or previous release of the first samples has been rejected
- - use of new or modified means (tools, machines)
- - the use of new or modified conditions (processes)
- - changing supplier or multiple suppliers for funds or conditions
- - changes or introduction of new control or test methods released in the production of the sample

Before the first serial samples are delivered, the product manufacturer must satisfy himself that the product meets all customer requirements. The control is performed by sampling in the laboratory and the results are compared with the drawing specifications. Subsequently, a report or measurement protocol shall be made of the measurement to be attached to the samples. If it is necessary to check the specifications that the manufacturer can not measure, it is necessary to provide written confirmation of performance of the test with specific results or to provide a test report from the certified testing center. For the first serial samples, it is checked whether the material used and the contents of the elements comply with the legal requirements and the customer's requirements with respect to the environment, safety and recycling. These data will be summarized in a document that is then stored in a material bank to give the so- IMDS (International Material Data System) and attaches to sample documentation.

The size of the sample documentation required for the release is divided according the category of submission into 5 categories:

Level 1: Customer will only be presented with proof of submission, PSW form

Level 2: The PSW is submitted to the customer along with the sample parts and limited sample documentation

Level 3: The PSW will be submitted to the customer together with sample parts and detailed sample documentation

Level 4: Present PSW and other fixed customer requirements

Level 5: The PSW is submitted together with the sample parts, and the complete supporting documentation is made available to the customer for on-site evaluation at the supplier.

Unless otherwise specified by the customer, according to the VDA6.5 standard for releasing the first serial samples it is necessary to remove and check, according to the drawing specification, 5 randomly selected parts from the serial process. If multiple or compound tools are used in the production process, 5 randomly selected pieces must be removed from each mould nest. In order to verify the suitability of the process of functionally important or specially labelled parameters, it is necessary to check at least 25 random sets of parts with 5 pieces. Before sending the first serial samples, the customer must be informed about the shipment. It is necessary that the shipment is properly identified to avoid confusion with the serial parts [5].

Upon submission of the samples and necessary documents to the customer, the appropriate quality assurance department at the customer performs the necessary inspection by own measurements in the laboratory. Verification of the first samples can be done directly by the manufacturer according to the stage of submission. On the basis of the measurements made and the checking of the accuracy of the documents submitted, the samples may be released, refused or released subject to the condition. The PSW Release Certificate [Annex 2] is signed by the customer and sent to the supplier who is qualitatively eligible to deliver the first series of parts to the customer immediately after receipt.

Process release

Unless otherwise agreed with the customer, the manufacturer of the product evaluates his serial production process according to the ISO / TS16949 or VDA6.3 standard separately, but in some cases, it is necessary that the process release check is carried out in the presence of the customer. The goal of the process is to determine if the serial production process is capable of producing products in accordance with the quality requirements of the required tool and production capacities within a set time. At the same time, it is checked whether the serial production process is in line with the production plan and quality plan. Verification of required performance must be carried out by complete production facilities in full capacity operation with the use of trained personnel and all support systems. The exact date of the inspection is the agreement between the manufacturer and the customer, but always before the first serial samples are delivered.

CONCLUSION

To ensure the quality of products produced in the automotive industry the principles set out in ISO / TS16949, VDA2 are applied. These provide an accurate framework of processes that determine the qualitative maturity of mass production products. These processes include the PPAP process and his sub-processes, product audit and manufacturing process audit. The main outcome of these steps is the successful release of the new product into the mass production by issuing a release certificate, a PSW document that guarantees that the product meets all the quality requirements set by customers as well as subsequent deliveries from series production.

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APPENDIX 1 – the list of submission levels according the PPAP process

Cis	Požiadavka	Objasnenie, komentár	Stupen predloženia				
			1	2	3	4	5
1	Konštrukcné podklady	Zákaznícky výkres (výkres so slzickami - pozíciami).	R	S	S	R	R
		Požiadavkový list, smernica dodávok produktu, technické podmienky dodávania	R	R	R	R	R
2	Dokumenty k zmenám	Dokumenty o zákazníkom odsúhlasených zmenách, ktoré ešte nie sú zdokumentované vo výkrese, ak tieto existujú.	R	S	S	R	R
3	Uvolnenie konštrukcie zákazníkom	Schválenie konštrukcie zákazníkom, ak je to na výkrese zákazníka požadované.	R	R	S	R	R
4	Systém- FMEA produkt/ Design- FMEA	Týka sa len dodávatelov so zodpovednostou za konštrukciu. Dokumentovat stav zmeny a dátum system- FMEA produkt/design- FMEA alebo priložit titulnú stranu.	R	R	S	R	R
5	Postupový diagram procesu	Postupový diagram procesu pre produkt alebo pre rodinu výrobkov	R	R	S	R	R
6	Systém- FMEA proces/ Proces- FMEA	Dokumentovat stav zmeny a dátum system- FMEA proces/proces- FMEA alebo priložit titulnú stranu.	R	R	S	R	R
7	Dimenzionálne výsledky merania	Kontrolná správa o rozmeroch všetkých parametrov na zákazníckom výkrese („Production Part Approval Dimensional Report – Prevzatie sériových dielov – výsledky merania").	R	S	S	R	R
8	Kontrolná správa o materiále a výsledky kontroly funkcie	Musia sa priložit údaje o materiále (analýza a tvrdost) ako 3.1 Osvedcenie skúšobného odberu. Vo formulári „Production Part Approval Material Test Results – Prevzatie sériových dielov – výsledky skúšok materiálu" je prípustný odkaz na 3.1 Osvedcenie skúšobného odberu. Nebezpecné látky sú uložené v systéme IMDS, vo výnimocných prípadoch je prípustný aj formulár „Production Part Approval Material Constituents – Prevzatie sériových dielov – obsah látok". Pri odlievaných dieloch sa musia vykonávat analýza materiálu na hotovom výrobku taktiež aj sa musia dodržat s odsúhlasením zákazníka vnútorné a vonkajšie chyby. Funkcné testy len v prípade ak sú požadované vo výkrese prípadne v požiadavkovom liste. („Production Part Approval Performance Test Report – Prevzatie sériových dielov – Správa z výkonnostných testov")	R	S	S	R	R
9	Zistovanie spôsobilosti procesu	Ako doklad treba uviest alternatívne Cm/Cmk-, Pp/Ppk-, alebo Cp/Cpk-hodnoty pre všetky dôležité a kritické parametre (spravidla je to oznacené na zákazníckom výkrese príp. definované dodávatelom).	R	S	S	R	R
10	Zistovanie spôsobilosti meradiel	Zistovanie spôsobilosti meradiel (napr.: R&R-Test alebo opakovatelnost pre kontrolné automaty) pre všetky meradlá uvedené v kontrolnom pláne; Potvrdenie pre všetky dôležité a kritické parametre v dokumentácii Sériový diel – postup uvolnenia.	R	R	S	R	R
11	Dokumentácia skúšobných laboratórií	V prípade využitia externých laboratórií je nutné dokladovat certifikát s udaním platnosti. Prírucka laboratória (alebo dokumentácia titulu a vydania) pre merové stredisko a laboratórium pre materiály, ak to zákazník požaduje.	R	R	S	R	R
12	Skúšobný plán	Kontrolný plán/Skušobný plán minimálne pre všetky dôležité a kritické parametre	R	R	S	R	R
13	Potvrdenie o predložení dielov	Použit „Part Submission Warrant PSW (Potvrdenie o predložení dielov)"	S	S	S	S	R
14	Správa o dieloch, pri ktorých sa kladie dôraz na vzhlad	Napr.:. Odsúhlasené katalógy chýb vzhladu, prevedenie lakovania ak to zákazník požaduje.	S	S	S	R	R
15	Kontrolný zoznam požiadaviek na surový materiál	Nerobí sa	R	R	R	R	R
16	Vzorkové diely	Skontrolovat 5 vzoriek pokial nie je zadané inak. Diely v sériovom balení podla listu údajov o balení.	R	S	S	R	R
17	Referencné vzorky	Dodávatel musí uchovávat minimálne jednu referencnú vzorku z každého hniezda po dobu výroby produktu plus jeden rok. Prostredníctvom jednoznacného oznacenia týchto referencných dielov treba zabezpecit priradenie ku kontrolnej správe o prvých vzorkách.	R	R	R	R	R
18	Meradlá/skúšobné pomôcky	Nerobí sa (len ak je to zvlášt požadované)	R	R	R	R	R
19	Další záznamy špecifikované zákazníkom	Ak je to v špecifikácii stanovenej zákazníkom požadované.	R	R	S	R	R

APPENDIX 2 – Part submission warrant

Part Submission Warrant

Part Name ______ Cust. Part Number ______

Shown on Drawing Number ______ Org. Part Number ______

Engineering Change Level ______ Dated ______

Additional Engineering Changes ______ Dated ______

Safety and/or Government Regulation ☐ Yes ☐ No Purchase Order No. ______ Weight (kg) ______

Checking Aid Number ______ Checking Aid Engineering Change Level ______ Dated ______

SUPPLIER MANUFACTURING INFORMATION

______
Organization Name & Supplier/Vendor Code

______
Street Address

______
City Region Postal Code Country

CUSTOMER SUBMITTAL INFORMATION

______
Customer Name/Division

______
Buyer/Buyer Code

______
Application

MATERIALS REPORTING

Has customer-required Substances of Concern information been reported ? ☐ Yes ☐ No ☐ n/a

Submitted by IMDS or other customer format: ______

If submitted by IMDS, enter Modul ID number, version and date transmitted ______

Are polymeric parts identified with appropriate ISO marking codes ? ☐ Yes ☐ No ☐ n/a

REASON FOR SUBMISSION (Check at least one)

☐ Initial submission
☐ Engineering Change(s)
☐ Tooling: Transfer, Replacement, Refurbishment, or additional
☐ Correction of Discrepancy
☐ Tooling Inactive > than 1 year
☐ Change to Optional Construction or Material
☐ Sub-Supplier or Material Source Change
☐ Change in Part Processing
☐ Parts produced at Additional Location
☐ Other - please specify below ______

REQUESTED SUBMISSION LEVEL (Check one)

☐ Level 1 - Warrant only (and for designated appearance items, an Appearance Approval Report) submitted to customer.
☐ Level 2 - Warrant with product samples and limited supporting data submitted to customer.
☐ Level 3 - Warrant with product samples and complete supporting data submitted to customer.
☐ Level 4 - Warrant and other requirements as defined by customer.
☐ Level 5 - Warrant with product samples and complete supporting data reviewed at supplier's manufacturing location.

SUBMISSION RESULTS

The results for ☐ dimensional measurements ☐ material and functional tests ☐ appearance criteria ☐ statistical process package
These results meet all design record requirements: ☐ YES ☐ NO (If "NO" - Explanation Required)
Mold / Cavity / Production Process ______

DECLARATION

I affirm that the samples represented by this warrant are representative of our parts which were made by a process that meets all Production Part Approval Process Manual 4th Edition Requirements. I further affirm that these samples were produced at the production rate of ______ / ___ hours using ______ production streams.. I also certify that documented evidence of such compliance is on file and available for review. I have noted any deviations from declaration below.

EXPLANATION/COMMENTS: ______

Is each Customer Tool properly tagged and numbered ? ☐ Yes ☐ No ☐ n/a

Organization Authorized Signature ______ Date ______

Print Name ______ Phone No. ______ Fax No. ______

Title ______ E-mail ______

FOR CUSTOMER USE ONLY (IF APPLICABLE)

Part Warrant Disposition: ☐ Approved ☐ Rejected ☐ Other ______

Customer Signature ______ Date ______

Print Name ______ Customer Tracking Number (optional) ______

Realization of Optimizing Procedures in the Conditions of the Selected Organization in Terms of Introducing Certified Disinfection

Gabriel Polo, Martin Balaz, Lubomir Belan, Maros Korenko, Jan Marecek, Eva Krcalova

Abstract: *The presented article on optimizing procedures can make a significant contribution to streamlining several steps, whether in terms of innovative, operational or complex coordination procedures and information in the field of certified disinfection of the interior of ambulances, but also in other areas of the national economy, such as the food industry. An important part of the article is the introductory introduction and the related sequence on the topic as well as the inter - innovative solution and the resulting verification as well as the control sequence of acquired knowledge and sequences. The information is given in the qualitative and developmental contexts, with an emphasis on achieving the highest possible effect for each of the optimized activities as well as on continual improvement within the general requirements and verification activities.*

Keywords: *optimizing, technology, certified disinfection, documentation*

INTRODUCTION

Modern technical and technological processes enable us to progressively accomplish innovations in technology and organizational succession [8, 16]. These steps need to be carefully monitored, based on the information gathered, to plan for possible improvements, whether in terms of qualitative or optimization bases, and subsequently to draw up an action plan to establish and verify the effectiveness of these procedures [10, 11, 12]. The article will present different types of assemblies with the help of high-quality information sources as well as professional connections to achieve high-quality solutions and process orientations [5, 6]. We will deal with the materials and methods used, their elaboration and the results obtained in order to increase the optimization and the quality of the processes in which the continuous sequence between the planned, controlled and implemented tools and the quality steps within the selected organization can contribute. We will state the used preparations and technologies, related processes and sequence with other process solutions, and the gradual elaboration of the results and the interrelationship of the mentioned information as a complex of processes.

Important issues related to this information are furthermore the results and discussions that in the given article will point us to usable benefits in terms of technical, technological and quality principles that can be further used for further improvement or further development of the quality tools such as the PDCA cycle as well as practical solutions in practice as part of the continuous improvement of organization processes [9, 13, 14, 15].

MATERIAL AND METHODS

In this part of the article, we will deal with material and methodical procedures, which have contributed significantly, to the compilation of this article in co-operation with specialized literature and quality information. We will deal with optimized disinfection technology for sanitary vehicles, which have significantly contributed, to the improvement of the quality of complex disinfection of ambulatory and cabin parts of ambulances. We will state the process sequences of the various technological processes, technologies and the necessary preparations for carrying out the certified disinfection of the sanitary vehicle interior. **Certified disinfection products used:** DEZISAN Profi is a concentrated liquid disinfectant designed for the certified disinfection of all washable surfaces, surfaces and equipment in medical facilities (also in the presence of people) as well as in sanitary vehicles of all types and their equipment and appliances, furthermore in food and public catering, in public transport, public spaces and their facilities. The preparation is for professional use and for certified disinfection. **Features:** in normal working concentrations does not damage any materials - it is non-corrosive. Treated surfaces do not change colour and properties. It does

not contain alcohol, aldehydes, phenols, and esters, no volatile or corrosive substances. It is non-flammable. It has no side effects. It is characterized by long-lasting antibacterial (G + and G-bacteria), antiviral (including Poliovirus, Adenovirus, BVDV virus, Vakcinie Virus) and antifungal (MM. Terrae, M. avium) effects. **Batching:** preventive disinfection of 20 ml of concentrate per 1 liter of water (2% solution) and disinfection of the infection deposit 50 ml concentrate to 1 liter of water (5% solution). The treatment results in a polymer layer that provides long-term protection against microorganisms. Do not wash the surface immediately after treatment. Minimum exposure time: 15 min. Water temperature does not affect the effect of the composition. Suitable for machine and hand disinfection. **Certified disinfection devices used:** Turbo ULV (ultra low volume) - ULV means extremely low power consumption. According to the definition of the World Health Organization, ULV means disinfection - the minimum use of a quantity of the preparation for certified disinfection.

ULV generator is a device that achieves the maximum effect with minimal consumption of Dezisan Profi. The device produces a soft fog (so-called cold fog) with a droplet size of 10 microns. Based on this certified disinfection technology, the product penetrates very quickly into all very small creases, corners, etc. The substance dries relatively quickly on disinfected surfaces and has a long-lasting effect. The benefits of this technology are in particular the efficiency of certified disinfection, high and long-term efficiency as well as a short application time cycle. Certification of products, i.e. the granting of the product conformity certificate with its specification according to the relevant standards is provided by legal or natural persons operating in the unregulated sphere accredited for the given area according to the cited norms. To these sequences, we will be accompanied by a conformity assessment process in the framework of certified and documented disinfection, where confirmation of conformity obtained by various processes, such as: mechanical testing, certification, demonstrated either compliance or non-compliance with the defined requirements. A declaration of conformity is the official declaration of the organization that carries out the conformity assessment in such a way that a particular product is fully in conformity with the prescribed conformity specifications. In accordance with these requirements also for disinfectants that are registered biocides, they are classified as certified products as they are certified by the Center for Chemicals and Preparations registered at the National Toxicology and Information Center tested according to ISO 17025.

RESULTS AND DISCUSSION

Within the results and expert discussion, we will highlight the important technological processes and benefits of these processes and their sequences. In the following picture, we can see a preparation, which is necessary to create a solution for performing an in-depth disinfection of the interior of ambulance vehicles, particularly in the ambulatory and particularly in the cabin part of the ambulance vehicle.

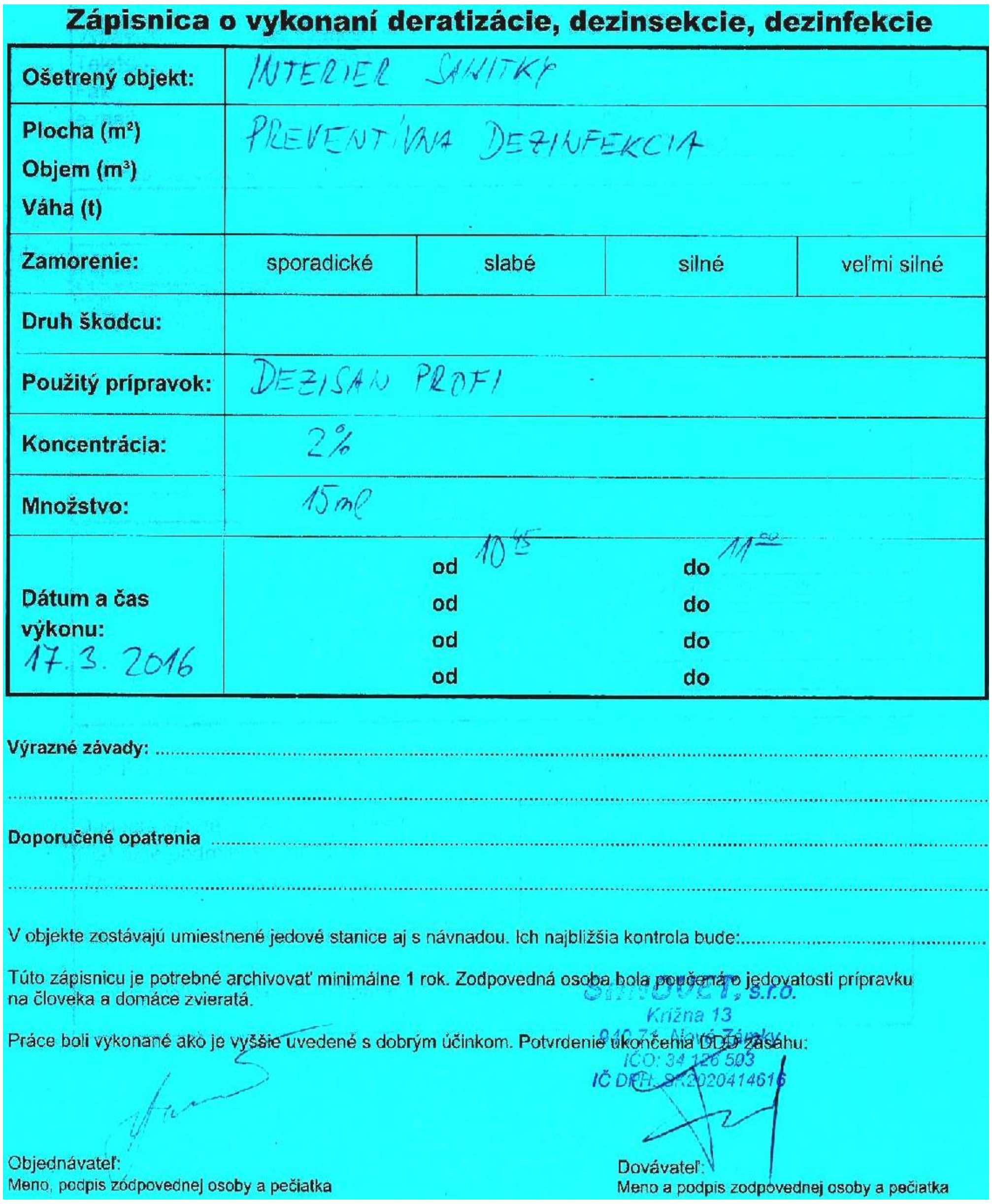
Fig. 1. Special preparation for mechanical disinfection of interior surfaces of an ambulance vehicle

Fig. 2. ULV generator type for cold mist generation to perform special certified disinfection in sanitary vehicles

When performing a certified disinfection, it is important to focus on the ambulatory and cabin parts of the sanitary vehicle, as this disinfection is highly effective for patient use as well as highly efficient and cost-effective (48 EUR with VAT / 1 certified disinfection). The effect of this disinfection is highly cost-effective, efficient and long-lasting, since spraying droplets of 10 microns forms a protective film on all surfaces that are not obtainable by manual disinfection. In connection with this information, we can mention other effective optimizing tools, for example: when introducing new tools and tools in ambulatory parts of sanitary vehicles, which after installation and introduction to the process are also disinfected with the ULV generator and Dezisan Profi disinfectant and thus eliminating the risk of possible occurrence or virus spread, and so on.

Fig. 3. ULV generator in the cold mist production process and long-term disinfection

After a certified disinfection by a certified organization, a record of the disinfection is printed, where the sanitized sanitary vehicle will be certified for 1 year. This highly efficient and safe technology delivers highly efficient results when disinfecting ambulances, with an emphasis on related information and context as one of the features of continuous improvement of processes within the selected organization.



Zápisnica o vykonaní deratizácie, dezinsekcie, dezinfekcie

Ošetrený objekt:	INTERIER SANITKY			
Plocha (m²) Objem (m³) Váha (t)	PREVENTÍVNA DEZINFEKCIA			
Zamorenie:	sporadické	slabé	silné	veľmi silné
Druh škodcu:				
Použitý prípravok:	DEZISAN PROFI			
Koncentrácia:	2%			
Množstvo:	15ml			
Dátum a čas výkonu: 17. 3. 2016	od 10⁴⁵ do 11⁰⁰ od do od do od do			

Výrazné závady: ....

Doporučené opatrenia ....

V objekte zostávajú umiestnené jedové stanice aj s návnadou. Ich najbližšia kontrola bude: ....

Túto zápisnicu je potrebné archivovať minimálne 1 rok. Zodpovedná osoba bola poučená o jedovatosti prípravku na človeka a domáce zvieratá.

Práce boli vykonané ako je vyššie uvedené s dobrým účinkom. Potvrdenie ukončenia DDD zásahu:

Objednávateľ: Meno, podpis zodpovednej osoby a pečiatka

Dovávateľ: Meno a podpis zodpovednej osoby a pečiatka

Fig. 4. Certificate of sanitary vehicle disinfection certified

In the context of the above-mentioned results and related objectives, due to the optimized procedures for certified disinfection as well as continuous improvement as a whole, we can conclude that the objective of continuous improvement of the quality management system is to increase the likelihood of reaching the satisfaction of customers and other stakeholders.

Continuous improvement is a repetitive action to increase the ability to meet requirements, is one of the basic principles of comprehensive quality management (TQM) and is one of the important principles underlying the requirements of quality management systems. Continuous improvement is an important part of achieving and maintaining competitiveness and should become a permanent goal for every organization. Therefore, the aforementioned basic model of continuous improvement is the Deming PDCA (Plan - Do - Check - Act) cycle. This cycle consists of the four phases in which the process of improving or making changes should take place. This is a cycle that does not end and should be repeated to ensure continuous improvement. In the following figure, we will show a general sequence of securing sterile surfaces and devices to ensure disinfection and subsequent sterility in terms of aseptic processing risks.

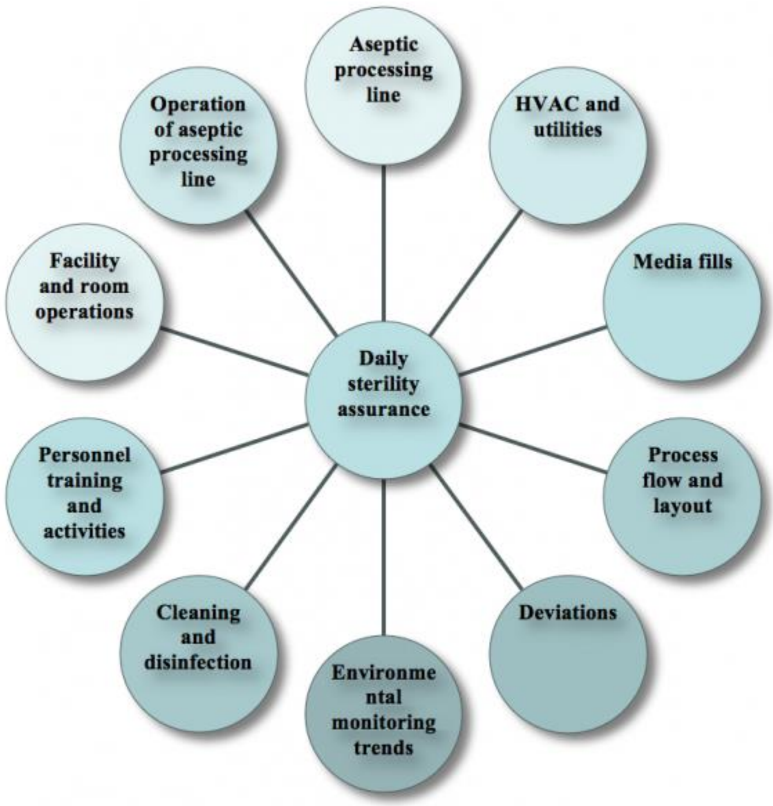


Fig. 5. Aseptic processing risks

On the basis of these important results and the information provided, they constitute a significant set-up and guidance for further continuous improvement also in the possible further builds of the mentioned PDCA cycles in cooperation with other tools of quality management systems, environment and work safety as optimization tools within the overall IMS (Integrated Management System) of the selected emergency health service organization.

CONCLUSION

This article presents important guidance on how to improve and increase the optimization and effectiveness of disinfection procedures not only in emergency health services but also in different sectors and orientations within the market structure of the national economy. With these technologies, certified technologies and the subsequent certification of their performance are important as they have a major impact on the safety and time required for disinfection in comparison with the manual disinfection technology for the interior of ambulances, as well as for workplaces such as hospitals as well as use in the food processing industry and other. To assemble this technology using a disinfectant that was tested by the manufacturer according to ISO 17025, a PDCA cycle in the form of P (plan to implement a certified disinfection) - D (make a certified test of the certified disinfection and its effectiveness) – C (control inter-disinfection operations and the resulting efficiency of tested ambulances) - A (conduct and, after approval, allow the continued use and monitoring of the technology). After rigorous verification, the technology was introduced in the selected organization as a preventive disinfection as well as an in-depth certified disinfection of sanitary vehicles to achieve high efficiency and optimization of disinfection of sanitary vehicles not only in terms of high level and comprehensive coordination of disinfection results, but also to increase overall efficiency, quality and process optimization as a whole.

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Comparative Research on Advanced Technologies for Minimum and Unconventional Soil Tillage with Application of Different Mulching Materials for Growing Wheat on Sloping Agricultural Lands

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Abstract: *In the Republic of Bulgaria a significant part of the arable lands are on sloping terrains, which is a prerequisite for the influence of the degradation processes soil water erosion, compaction and loss of the soil organic matter. For their limitation, advanced soil protection technologies have been developed and studied, including technological processes surface and vertical (into the soil) mulching with the application of mulch materials compost and manure. The present research explores the results of long-term comparative studies with these technologies for growing wheat on slope areas in specific soil and climatic conditions and evaluates their agro technical and soil protection capabilities.*

Keywords: *soil water erosion, compaction, loss of soil organic matter, wheat, minimum and unconventional soil tillage, surface mulching, vertical mulching, compost, manure*

INTRODUCTION:

In the Republic of Bulgaria, wheat is the main bakery and cereal crop. It is the most widespread culture and 45.2% of the country's arable land and 51.7% of the cereal crop area are occupied with wheat (Dimitrov, 2008). Our research has found that between 1.0 and 1.3 million hectares of wheat, are sown every year, and bigger part of these sowings are (about 45-50%) spread over terrains with different slopes that are potentially threatened by impact of water erosion processes (Dimitrov, 2008, 2016). Moreover on these areas act and closely related to water erosion and dependent on it, degradation processes, soil compaction and loss of organic matter. The losses caused to the agriculture of Bulgaria by these three degradation processes are enormous and have serious consequences for both our agricultural production and of our national economy as a whole. They are a problem of general national importance, the solution of which, for cultivating agricultural crops on sloping terrains, can’t be achieved with the established conventional technologies, and requires including of some soil protection measures with high runoff control and soil protection efficiency.

Minimum soil tillage is a measure that can be successfully applied to control water erosion as well as soil compaction and depletion of organic matter. The improvement of these technologies and their combination with the unconventional soil tillage surface and vertical mulching with organic materials of plant origin in order to further improve the humus content of the soil and counteract the loss of the organic matter is carried out by the Institute of soil science, agrotechnologies and plant protection "Nikola Pushkarov" - Sofia, together with University of Ruse "Angel Kanchev". These new advanced technologies for minimum and unconventional soil tillage are created in two variants, the first - using ready compost as mulching material and the second with application of cattle manure. With these two variants of technology, multi-year comparative studies have been conducted, with positive results.

The purpose of the present study is to identify and compare their agro-technical and soil protection capabilities on growing wheat on sloping agricultural lands, based on the results of these comparative studies between advanced soil protection technologies for minimum and unconventional soil tillage using ready compost or cattle manure.

MATERIAL AND METHODS

The assays were carried out in the experimental field of the Nikola Pushkarov Institute of Soil Science, Agrotechnologies and Plant Protection in the territory of the village of Trastenik in the Ruse region on non-irrigated areas, on a medium eroded calcareus

chernozem, on a slope of 5º (8,7%). They were conducted during the period 2013-2017y., in two stages. The first stage of the experiment was carried out in 2013-2015y. Field experiment with wheat has been established and developed with soil protection technologies for minimum and unconventional soil tillage with the application of ready compost as mulching material. The second stage of the study was carried out in the period 2015-2017y., and during it were tested the agro technical and soil protection efficiency of the erosion control technologies for minimum and unconventional soil tillage with application of manure. To achieve the goal of the research, both experiments were conducted by block method with four variants and four replicates. The experiments are single factor, as the applied soil protection technologies (limiting water erosion, compaction and reduction of soil organic matter) are the factor.

The variants during the first stage of the experiments are:

1 st variant - wheat plots, grown by conventional technology, applied along the slope - control;

2 nd variant - wheat plots, grown by conventional technology, applied across the slope;

3 rd variant - wheat plots, grown by soil protection technology including the erosion control measure - surface mulching with ready compost, applied across the slope.

4 th variant - wheat plots, grown under advanced soil protection technology including erosion control measures vertically mulching with ready compost and direct sowing, as well as some plant protection operations for weed control, pests and plant diseases, all applied across the slope.

The variants of field experiment in the second stage of research are:

5 th variant - wheat plots, grown by conventional technology, applied along the slope - control;

6th crop - wheat plots, grown by conventional technology, applied across the slope;

7th - wheat plots, grown by soil protection technology including the erosion control measure - surface mulching with manure, applied across the slope

8th - wheat plots, grown under the advanced soil protection technology including erosion control measures vertically mulching with manure and direct sowing, as well as some plant protection operations to control weeds, pests and plant diseases, all operations applied across the slope.

During the research period, both control variants of the two experiments (variant 1 and variant 5) are common, conventional for this agricultural crop and are carried out along the slope. The same conventional technological operations were performed in variants 2 and 6, but with the difference that in them the direction of their application is across the slope. The erosion control agro-technical measures, in the other variants, were applied using the relevant methods in the following ways. Surface mulching, in variants 3 and 7, is performed across the slope with fertilizer spread trailer 1PTU – 6 (fig.1, at a rate of 4500-5000 kg/ha with mulch material - compost during the first stage 3) and manure in the second. Vertical mulching, in variants 4 and 8, was accomplished across the slope, pre-sowing at both stages of the experiment with the reconstructed machine cutter-dead furrower SHTN 2-140 with bunker for mulch (fig. 2) (with a distance between the pair of slits -1.4 m and a band intervals 3 m in the field) at a depth of 0.40 m, with compost in variant 4 for mulching material, and in case of variant 8 this material is manure. In both cases the norm is 4500-5000 kg/ha, and simultaneously with this technological operation was performed a single disking with heavy disc harrows for surface covering of slots and soil moisture conservation as well as fertilizer plowing.

Fig. 1 Fertilizer spread trailer 1PTU – 6

Fig. 2 Machine for vertical mulching SHTN 2- 140 with bunker for mulch

The direct sowing, which provides qualitative sowing of the wheat seeds without additional pre-sowing tillage of the terrain and which, according to Beloev (2008), safes the soil structure, slows the humus mineralization, improves the subsurface soil water permeability and reduces the erosion, is performed in both variants (4 and 8), with a seed drill cultivator SCS-2 (fig. 3). In the untilled field, this machine in a tractor unit with a tractor pulling capacity of 14 kN (fig. 4) performs four technological operations simultaneously: pre-sowing soil tillage, sowing, imports granulating fertilizers and rolling. Subsequent combating of weeds, pests and plant diseases, in these variants, is carried out exclusively by chemical methods, using pesticides.

Fig. 3 Seed drill cultivator SCS-2 “Belarus 952”

Fig. 4 General view of sowing aggregate and a seed drill cultivator SCS-2

During the two phases of the reported period, the experiments performed agrotechnical (soil and biometric) and erosion observations according to established methodology.

RESULTS AND DISCUSSION

The results obtained from the comparative studies carried out with the advanced soil protection technologies for minimum and unconventional soil tillage using compost or manure as mulching materials in wheat growing on sloping terrains show that their application has a positive impact on agro-technical and erosion indicators.

Table 1 *Bulk density (g/cm^3), total porosity(%) soil hardiness (kg/m^2) in layer 0-40 cm, experiment 2013-2015 y.*

Year, variant	Before sowing			Maximum growth stage			Harvesting		
	Bulk density	Total porosity	Hardiness	Bulk density	Total porosity	Hardiness	Bulk density	Total porosity	Hardiness
2013									
1	1.32	51.29	15.83	1.42	47.60	30.69	1.39	48.71	26.83
2	1.27	53.14	14.70	1.37	49.45	29.27	1.35	50.18	25.90
3	1.24	54.24	14.48	1.22	54.98	23.34	1.34	50.55	23.61
4	1.20	55.72	13.65	1.17	56.83	22.03	1.26	53.51	22.87
2014									
1	1.35	50.19	17.20	1.44	46.86	31.43	1.43	47.23	20.81
2	1.32	51.29	15.72	1.43	47.23	26.78	1.39	48.71	18.63
3	1.27	53.14	15.05	1.37	49.45	17.75	1.32	50.19	13.60
4	1.24	54.24	14.61	1.20	55.72	14.80	1.25	53.87	12.15
2015									
1	1.33	50.92	19.02	1.37	49.45	45.03	1.35	50.18	41.97
2	1.33	50.92	19.02	1.32	51.29	41.79	1.30	52.03	37.61
3	1.27	53.14	18.25	1.22	54.98	22.31	1.29	52.40	27.03
4	1.24	54.24	15.18	1.20	55.72	17.60	1.18	56.46	22.49
2013-2015									
1	1,33	50,80	17,35	1,41	47,97	35,72	1,39	48,71	29,87
2	1,31	51,78	16,48	1,37	49,32	32,61	1,35	50,31	27,38
3	1,26	53,51	15,93	1,27	53,14	21,13	1,32	51,05	21,41
4	1,23	54,73	14,48	1,19	56,09	18,14	1,23	54,61	19,17

Bulk density *p= 0.001485HSD[0.05]=0.09; HSD[0.01]=0.12 1 vs 2 NS; 1 vs 3 P<0.05; 1 vs 4 P< 0.01; 2 vs 3 NS; 2 vs 4 P<0.01 ; 3 vs 4 NS;* ***Hardiness*** *p=0.251675*

Table 2 *Bulk density (g/cm^3), total porosity(%) soil hardiness (kg/m^2) in layer 0-40 cm, experiment 2015-2017y.*

Year, variant	Before sowing			Maximum growth stage			Harvesting		
	Bulk density	Total porosity	Hardiness	Bulk density	Total porosity	Hardiness	Bulk density	Total porosity	Hardiness
2015									
5	1.33	50.92	19.02	1.37	49.45	45.03	1.35	50.18	41.97
6	1.33	50.92	19.02	1.32	51.29	41.79	1.30	52.03	37.61
7	1.27	53.14	18.25	1.22	54.98	22.31	1.29	52.40	27.03
8	1.24	54.24	15.18	1.20	55.72	17.60	1.18	56.46	22.49
2016									
5	1.32	51.29	23.08	1.41	47.97	37.72	1.38	49.08	35.32
6	1.32	51.29	19.84	1.40	48.34	35.11	1.37	49.45	31.84
7	1.30	52.03	18.31	1.35	50.18	32.40	1.33	50.92	23.78
8	1.21	55.35	15.37	1.28	52.77	21.13	1.27	53.14	16.68
2017									
5	1.29	52.40	17.61	1.31	51.66	24.51	1.30	52.03	27.25
6	1.29	52.40	17.61	1.24	54.24	21.34	1.27	53.14	24.33
7	1.27	53.14	16.10	1.17	56.83	18.26	1.25	53.88	21.14
8	1.23	54.73	14.52	1.16	57.20	17.42	1.22	54.98	19.71

ANOVA: Bulk density *p=0.000175; HSD[0.05]=0.05; HSD[0.01]=0.06; 5 vs 6 NS; 5 vs 7 P<0.01; 5 vs 8 P<0.01; 6 vs 7 NS; 6 vs 8 P<0.01; 7 vs 8 P<0.05;* ***Total porosity****: p=0.000175; HSD[0.05]=1.68; HSD[0.01]=2.29; 5 vs 6 NS; 5 vs7 P<0.01; 5 vs 8 P<0.01; 6 vs 7 NS; 6 vs8 P<0.01; 7 vs8 P<0.05; Hardiness; p= 0.127096*

The results in table 1 and table 2 show that the values of bulk density, hardness and total porosity of the soil using these technologies, including soil protection methods vertical mulching with compost or with manure and direct sowing in all three phases of observation and during both stages of the experiment are best compared to applied conventional technologies and are almost the same as in the use of compost, and when manure is incorporated as a mulching material. In these two cases soil parameters are in optimal range (for bulk density 1.2-1.3g/cm^3, for general porosity 50-55% and for soil hardness 15-19

kg/cm^2) for growing wheat on slopes (Todorov et al., 1982). This allows better development of the root system of this crop, to improve the moisture holding capacity, the nutritional and air regime of the soil.

Lower but relatively high are soil indicators with application of the second soil protection technology, which involves surface mulching at both stages of the study, the first using compost and the second with manure.

Similar are results of the observation of the height of the plants (table 3 and table 4) as well as the average yields of wheat straw and wheat grains (table 5, table 6, table 7 and table 8) .

Table 3 *Height of plants by phases of development (cm) wheat experiment 2013-2015y.*

Variant	Phase of development			Phase of development			Phase of development			Phase of development		
	stem elongation	heading	flowering	stem elongation	heading	flowering	stem elongation	heading	Flowe ring	stem elongation	heading	flowering
	2013			2014			2015			2013-2015		
1	32.50	45.10	60.30	48.92	57.80	66.67	41.00	52.15	72.20	40,81	51,68	66,39
2	33.60	46.50	66.10	57.34	76.00	76.00	44.10	60.30	85.30	45,01	60,93	75,80
3	38.50	50.40	69.50	67.20	77.60	92.67	48.30	67.50	92.50	51,33	65,17	84,89
4	40.10	52.30	72.50	73.72	88.00	100.67	51.60	75.20	97.70	55,14	71,83	90,29

ANOVA: ***For flowering phase;*** *p= 0.140272, 1 vs 3 p=0.093124; 1vs4 p= 0.067053*

Table 4 *Height of plants by phases of development (cm) wheat experiment 2015-2017 y.*

Variant	Phase of development			Phase of development			Phase of development			Phase of development		
	stem elongation	heading	flowering	stem elongation	heading	flowering	stem elongation	heading	flowering	stem elongation	heading	flower ing
	2015			2016			2017			2015-2017		
5	41,00	52,15	72,20	41,50	48,92	74,20	43.80	51.20	78.40	42.10	50.76	74.93
6	44,10	60,30	85,30	47,80	57,34	86,00	48.10	58.80	87.50	46.67	58.81	86.27
7	48,30	67,50	92,50	48,00	67,20	93,60	49.50	72.70	95.70	48.60	69.13	93.93
8	51,60	75.20	97,70	53,00	73,72	98,80	54.60	74.67	99.30	53.07	74.53	98.60

ANOVA: ***For flowering phase*** p<.0001; HSD[.05]=5.01; HSD[.01]=6.84; 5 vs 6 P<.01; 5 vs 7 P<.01; 6 vs 8 P<.01; 6 vs 7 P<.01; 6 vs 8 P<.01; 7 vs 8 nonsignificant

The height of plants, on average during the study period, is the highest, with the application of advanced soil protection technology for minimum and unconventional soil tillage (vertical mulching) and in the three phases of plant observation – stem elongation, heading and flowering. By comparing this indicator, the two stages of the experiment using compost or manure as mulching material (variant 4 and variant 8) show that the values in all three phases of development are close with a slight prevalence for those in which was applied manure as a mulch - variant 8. The same is also observed with the use of soil protection technology, including the erosion control method, surface mulching with manure (variant 7), although the plant heights are smaller compared to these with realization of the vertical mulching.

***Table 5** Grain yield at 14% humidity, 2013-2015y.*

	Yeild							
Year	**2013y.**		**2014y.**		**2015y.**		**2013-2015y.**	
Variant	**kg/ha**	**%**	**kg/ha**	**%**	**kg/ha**	**%**	**kg/ha**	**%**
1	3411	100,0	3871	100,0	3928	100.0	3736,67	100
2	3575	104,8	4042	104,4	4112	104.7	3910,67	104,6
3	3726	109,2	4203	108,6	4262	108.5	4063,67	107,8
4	4154	121,8	4649	120,1	4702	119.7	4501,67	120,5
GD5%	66.07	1.94	50.55	1.31	43.50	1.10		
GD1%	94.93	2.66	76.58	1.89	65.86	1.60		
GD0,1%	139.66	3.75	123.10	2.93	105.86	2.43		

***Table 6** Average yield of wheat straw 2013-2015 y.*

Year, Variant	**Yeild**							
	2013y.		**2014y.**		**2015y.**		**2013-2015y.**	
	kg/ha	**%**	**kg/ha**	**%**	**kg/ha**	**%**	**kg/ha**	**%**
1	2707	100,0	3029	100,0	3103	100.0	2946,33	100,0
2	2813	103,9	3141	103,7	3226	104.0	3060,00	103,9
3	2987	110,9	3318	109,5	3378	108.9	3227,67	109,8
4	3245	119,9	3594	118,7	3654	117.8	3497,67	118,8
GD5%	56.69	2.09	95.85	3.16	26.64	0.86		
GD1%	81.44	2.90	145.19	4.62	40.36	1.25		
GD0,1%	119.81	4.01	233.40	7.03	64.88	1.92		

***Table 7** Grain yield at 14% humidity, 2015-2017 y.*

Year, Variant	**Yield**							
	2015y.		**2016y.**		**2017y.**		**2015-2017 y.**	
	kg/ha	**%**	**kg/ha**	**%**	**kg/ha**	**%**	**kg/ha**	**%**
5	3928	100,0	4437	100,0	4827	100.0	4397.3	100.0
6	4112	104,7	4623	104,2	5059	104.8	4598.0	104.6
7	4262	108,5	4779	107,7	5165	107.0	4735.3	107.7
8	4702	119,7	5219	117,6	5622	116.5	5181.0	117.8
GD5%	39.24	11.50	25.26	0.57	6.06	1.78		
GD1%	56.38	15.77	38.26	0.83	8.71	2.43		
GD0,1%	82.94	22.263	61.50	1.29	12.82	3.44		

***Table 8** Average yield of wheat straw 2015-2017 y.*

Year, Variant	**Yeild**							
	2015y.		**2016y.**		**2017y.**		**2015-2017y.**	
	kg/ha	**%**	**kg/ha**	**%**	**kg/ha**	**%**	**kg/ha**	**%**
5	3103	100,0	3413	100,0	3730	100.0	3415.3	100.0
6	3226	104,0	3540	103,7	3881	104.1	3549.0	103.9
7	3378	108,9	3699	108,4	4024	107.9	3700.0	108.4
8	3654	117,8	3986	116,8	4317	115.7	3985.7	116.7
GD5%	42.45	3.01	20.55	0.60	6.04	0.16		
GD1%	64.31	4.33	31.13	0.88	9.14	0.24		
GD0,1%	103.38	6.70	50.04	1.35	14.70	0.37		

This gradation of the variants on their agro-technical efficiency, as shown in table 5 and table 6, table 7 and table 8 is also maintained taking into account the average yields of wheat and wheat straw. The highest average yields using the improved soil technology were in both stages of the experiment (variant 4 and variant 8). In the period 2013-2015y. the average grain

yield in variant 4 using compost as mulching material is 765.0 kg/ha (with 20.5%) higher than variant conventionally grown along the slopes (control - variant 1), with 591.0 kg/ha (with 15.1%) higher than that of the variant conventionally tilled across the slope and 438.0 kg/ha (with 12.7%) higher than this of crop grown under soil protection technology, including surface mulching with ready compost. This tendency is also maintained in the results with the average annual yield of wheat straw at this stage. Here the increase of this indicator in variant 4, compared to the control - variant 1 is 551.34 kg/ha (with 18.8%) compared to variant 2 with 437.7 kg/ha (with 14.9%), and compared to variant 3 is 270.0 kg/ha (with 9.0%).

In the second stage of the survey (2015-2017y.), data for yields are similar to the average wheat grain in variant 8, using the vertical mulching method, with the mulch material manure was 783.7 kg/ha (with 17.8%) higher than that of the conventionally grown along the slope control - variant 5 with 583.0 kg/ha (with 12.7%) higher than conventionally grown across the slope - variant 6 and 445.7 kg/ha (with 9.4%) higher than that of variant 7, with application of the soil protection technology, including surface mulching with manure. At the average yield of wheat straw, at this stage, the yield increase in variant 8 compared to the control was 570.4 kg/ha (with16.7%) at variant 6, it was 436.7 kg/ha (12.3%) compared to variant 7, the increase was 285.7 kg/ha (7.7%).

Comparing all these results for the obtained yields, it can be seen that even with these indicators, their values are the highest and at the same time very close, in the variants using the advanced soil protection technologies for minimum and unconventional soil tillage, including vertical mulching with ready compost or bovine manure and direct sowing (variant 4 and variant 8), with slightly preponderance in the case of manure application as a mulching material.

These technologies, in both applications (with compost or manure, as mulch), wheat growing on sloping terrains have a higher erosion control effect compared to other examined technologies, both during the two experimental stages (table 9 and table 10). This, according to Dimitrov (2016), is due to the increased water permeability of the soil and the improved soil protection effect of vegetation and organic residues, reflecting both the volume of surface water runoff and the amount of eroded soil.

Table 9 *Total volume of surface water runoff and amount of eroded soil 2013-2015 y.*

Date	**Rain l/m²**	**Surface water runoff m³/ha**				**Eroded soil kg/ha**			
		Variant				**Variant**			
		1	**2**	**3**	**4**	**1**	**2**	**3**	**4**
14.04.13	17.5	112.071	75.306	63.434	39.231	1327.9	700.8	406.9	204.5
12.06.13	28.0	101.143	74.289	63.253	37.633	1151.2	626.9	366.9	182.7
13.06.13	12.0	89.143	64.082	53.494	31.953	948.1	592.9	301.1	149.0
For 2013 y.	57.5	302.357	213.674	180.181	108.817	3427.2	1920.6	1074.9	536.2
14.05.14	18.0	137.442	106.192	92.913	55.455	1658.1	971.6	552.6	267.1
31.05.14	54.0	115.814	76.603	64.702	38.485	1368.2	716.1	415.9	209.8
18.06.14	30.0	126.628	88.767	81.206	46.667	1572.9	869.1	504.2	249.3
For 2014 y.	102.0	379.884	271.562	238.821	140.607	4599.2	2556.8	1472.7	726.2
26.05.15	16,0	165,985	128,000	103,794	64,483	1983,2	1181,9	640,8	315,0
10.06.15	18,0	140,584	93,895	80,643	50,344	1663,9	884,0	510,9	258,3
02.07.15	14,5	118,467	78,947	66,945	41,552	1397,9	763,9	432,7	215,7
For 2015 y.	48,5	425,036	300,842	251,384	156,379	5045,0	2829,8	1584,4	789,0
Avarage for 2013-2015 y.	69,33	369,092	262,026	223,462	135,268	4357,1	2453,7	1377,3	683,8

***ANOVA: Surface water runoff** , p<0.0001 HSD[0.05]=22.9; HSD[0.01]=28.49, 1 vs 2 P<0.01, 1 vs 3 P<0.01, 1 vs4 P<0.01, 2 vs 3 NS, 2 vs 4 P<.01, 3 vs 4 P<.01; **Eroded soil** , p< .0001; HSD[0.05]=241.15; HSD[0.01]=300; 1 vs 2 P<0.01, 1vs 3 P<0.01; 1 vs 4;P<0.01 ; 2 vs 3 P<0.01; 2 vs 4 P0<0.01; 3 vs 4 NS*

Table 10 *Total volume of surface water runoff and amount of eroded soil 2015-2017y.*

Date	Rain l/m^2	Surface water runoff m^3/ha				Eroded soil kg/ha			
		Variant				Variant			
		5	6	7	8	5	6	7	8
26.05.15	16.0	165.985	128.000	103.794	64.483	1983.2	1181.9	640.8	315.0
10.06.15	18.0	140.584	93.895	80.643	50.344	1663.9	884.0	510.9	258.3
02.07.15	14.5	118.467	78.947	66.945	41.552	1397.9	763.9	432.7	215.7
For 2015y.	48.5	425.036	300.842	251.384	156.379	5045.0	2829.8	1584.4	789.0
05.05.16	20.0	170.382	122.628	101.661	63.761	1925.1	1079.5	605.9	301.4
24.05.16	16.0	148.397	98.978	89.302	52.657	1598.2	926.0	491.3	247.5
06.06.16	12.0	109.924	73.577	62.193	37.687	1211.9	651.9	355.0	185.7
12.06.16	18.0	142.443	100.292	83.721	50.866	1567.1	888.2	471.7	243.6
For 2016 y.	66.0	571.146	395.475	336.877	204.971	6302.3	3545.6	1923.9	978.2
29.04.17	16.0	152.528	103.830	90.863	56.556	1578.8	878.9	495.2	246.3
06.05.17	20.2	165.626	123.319	99.604	62.284	1900.2	1062.3	598.9	300.4
27.05.17	13.0	105.934	71.915	59.808	36.979	1128.2	604.1	341.0	173.4
19.06.17	11.0	106.374	71.489	59.425	36.616	1136.1	602.9	337.3	175.2
02.07.17	32.0	169.231	128.511	103.898	65.619	2035.6	1206.2	654.2	324.3
For 2017 y.	92.2	699.693	499.064	413.398	258.54	7778.9	4354.4	2426.6	1219.6

ANOVA; ***Surface water runoff***: p<.0001;HSD[.05]=21.62; HSD[.01]=26.67; 5 vs 6 P<.01;5 vs 7 P<.01; 5 vs 8 P<.01; 6 vs 7 nonsignificant; 6 vs 8 P<.01; 7 vs 8 P<.01; **Eroded soil** p<.0001; HSD[.05]=223.02; HSD[.01]=275.14; 5 vs 6 P<.01; 5vs7 P<.01; 5 vs 8 P<.01; 6 vs 7 P<.01; 6 vs 8 P<.01; 7 vs 8 P<.05

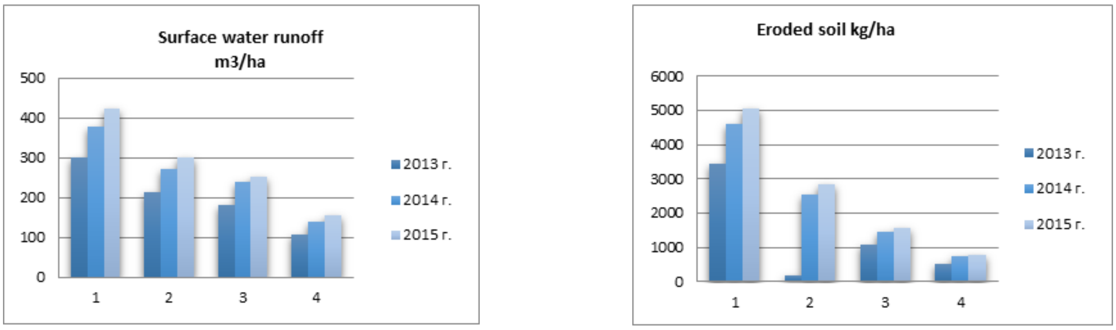

Fig. 5 Volume of surface water runoff (m3/ha) and amount of eroded soil (kg/ha) 2013-2015 y

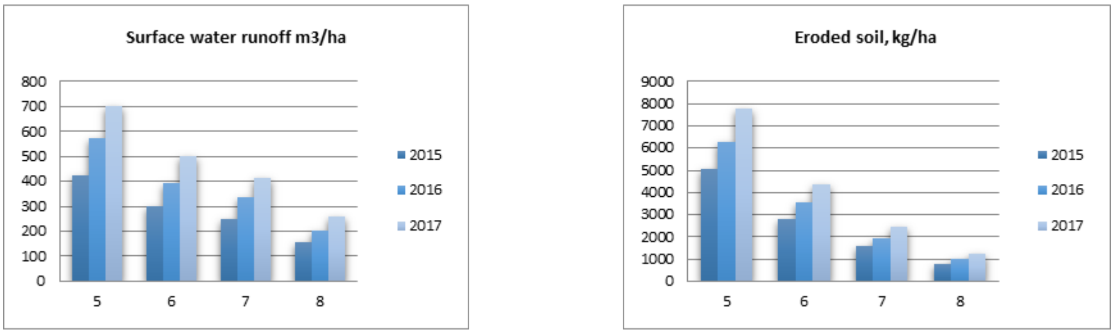

Fig. 6 Volume of surface water runoff (m3/ha) and amount of eroded soil (kg/ha) 2015-2017

Data on table 9 and fig. 5 show that in the first stage of the survey, in the period 2013-2015 y., the use of advanced soil protection technology including vertical mulching with compost and direct sowing, average annual water surface runoff values decreased from 2.5 to 3.0 times, and those of the eroded soil from 6.2 to 6.5 times, compared to conventional grown plots along the slope - control, variant1.

During the second stage of the experiment (2015-2017y.), in the variant with application of advanced soil protection technology including vertical mulching with manure

and direct sowing, as shown in table 10 and fig. 6, this decrease in surface water runoff is almost the same as in the first stage, from 2.6 to 2.9 times, and in the quantity of eroded soil it is 6.3 to 6.5 times, compared to the control. A weaker erosion control effect was observed in variants 3 and 7 with the application of soil protection technology using the surface mulching method with manure. In the first stage of the experiment, when the mulching material is compost, the reduction of the surface water flow is 1.5 to 1.8 times, and for the eroded soil is 3.0 to 3.3 times, compared to control (fig. 5), this decrease in surface water runoff and soil loss relative to the control variant 5 during the second stage of the study, using this technology applying surface manure mulching, is 1.6 to 1.8 times, and in the water runoff from 3.1 to 3.4 times for the eroded soil (fig. 6).

CONCLUSION

Taking into consideration the results of the comparative study of the improved soil protection technologies for minimum and unconventional tillage of the soil by application of the erosion control method vertical mulching with different mulching materials, as well as soil protection technologies with the application of surface mulching with these materials for growing wheat on sloping agricultural lands, we can draw the following conclusions:

1. The two advanced soil protection technologies for minimum and unconventional soil tillage for wheat growing on inclined terrains, including vertical mulching with compost in first and manure in the other, as well as direct sowing in both on the calcareous chernozem, are applicable in the Republic of Bulgaria and are a reliable means of protecting the soil from the degradation processes - water erosion, compaction and loss of soil organic matter, on sloping agricultural lands with a slope of 5 ° (8.7%).

2. The application of advanced soil protection technologies for wheat growing on sloping terrains, in both variants, including erosion control methods vertical mulching with compost and direct sowing, in the first variant and vertical mulching with manure and direct sowing, in the second, help to obtain and maintain soil density, hardness and total porosity close to the most favorable for the cultivation and development of this crop, as evidenced by the high biometric values obtained, indicating higher average yields of grain and wheat straw. In the first variant, the use of compost as a mulching material was higher with 765.0 kg/ha (with 20.5%) for grain and 551.3 kg/ha (with 18.8%) at the straw compared to the conventional grown wheat plots along the slope, and in the second variant using for mulch manure, this increase is slightly higher by 783.7 kg/ha (with 17.8%) for the grain and 570.4 kg/ha (with 16.7%) for the straw compared to the control.

3. The runoff and erosion control efficiency of advanced soil protection technologies for wheat growing on sloping terrain in both variants of work using compost as mulching material and manure as a mulch are greater than those at conventionally used for growing this agricultural crop technology. In their application, in the first variant, the values of the surface water runoff decrease from 2.5 to 3.0 times, those of the eroded soil from 6.2 to 6.5 times compare to the conventionally grown sowings along the slope. In the second variant, this decrease is almost the same as for the surface water runoff of 2.6 to 2.9 times, and for the soil removed it is 6.3 to 6.5 times as compared to the control.

4. The application of the two soil protection technologies for growing wheat on slopes using the erosion control method of surface mulching with compost in the first and surface mulching with manure in the second, also has a relatively good soil protection role. Both types of mulching materials reduce surface water runoff to 1.8 times and for the eroded soil to 3.3-3.4 times compare to the control. In addition, they increased the average yield of grain by 327 kg/ha (with 8.8%) and wheat straw by 281.34 kg/ha (with 9.6%), compared to conventionally grown sowings along the slope in the first experiment, and in the second increase was 338.0 kg/ha (with 7.7%) for grain and 284.7 kg/ha (8.3%) for wheat straw.

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Comparative Research on Advanced Technologies for Minimum and Unconventional Soil Tillage with Application of Different Mulching Materials, for Growing Maize for Grain, on Sloping Agricultural Lands

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Abstract: *Annually between 400,000 and 500,000 hectares of grain maize are grown in the Republic of Bulgaria, with about 50% of these areas being sown on sloping agricultural lands. On these terrains, the risk of soil degradation and in particular the risk of degradation processes, water erosion, compaction and loss of soil organic matter is significant. In order to reduce this danger or to prevent it, along with the many applied soil protection methods and technologies in our country, advanced technologies for minimum and unconventional soil tillage have been developed and studied. These include both combined reduced tillage system and the erosion control method of mulching (surface and vertically-into the soil), with ready compost or manure as a mulching material. The present research explores the results of long-term comparative studies with these technologies in the cultivation of grain maize on sloping agricultural lands in specific soil and climatic conditions, assessing their agro technical and soil protection capabilities.*

Keywords: *soil water erosion, compaction, soil organic matter reduction, grain maize, minimum soil tillage, surface mulch, vertical mulch, ready compost, manure.*

INTRODUCTION:

Annually about 400,000 hectares of grain maize are sown in the Republic of Bulgaria, which occupies 12.6% of the arable land (Dimitrov, 2008). An important requirement for growing this crop is to place it on plane terrains, free of water erosion, compaction and loss of soil organic matter. The erosion assessment of the relief of our country, made by Rousseva (2006) shows, that only 16% of our total territory has a slope of 0^0 to 3^0, and the rest is with bigger inclinations. This requires a large part, about 40-50% of the maize crops, to be located on terrains with different slopes, which are potentially at risk by the degradation processes of the soil (Dimitrov, 2008, 2016). In these areas, the implementation of established conventional technologies does not solve the problems of degradation, and even according to Dimitrov (2008), it can accelerate their development, especially if the operations are carried out along the slope. For this reason, on sloping agricultural lands sown with grain maize, it is necessary to use modern soil protection technologies aimed at limiting or completely preventing the degradation processes - water erosion, compaction and loss of organic matter. One of them is the advanced soil protection technology for minimum and unconventional soil tillage. It includes both combined systems for reduced tillage (loosening, making slits with ducts, along with sowing and digging and furrowing along the hilling) and the erosion control method vertical (into the soil) mulching using compost or manure, in two mulch variants. At the Institute of Soil Science, Agrotechnology and Plant Protection "Nikola Pushkarov" – Sofia and University of Rousse “Angel Kanchev”, joint research was carried out with these two variants of the advanced soil protection technology under particular soil and terrain conditions, from which positive results were obtained.

The aim of the present study is on the base of the results of comparative research, between the two variants of the work, the advanced soil protection technology for minimum and unconventional soil tillage using compost or manure as a mulching material, to compare their agrotechnical and soil protection capacities for growing maize for grain on sloping agricultural lands.

MATERIAL AND METHODS

The essays were conducted in the experimental field of the Nikola Pushkarov Institute of Soil Science, Agrotechnology and Protection of Plants in the territory of the village of Trastenik in the Ruse region, on non-irrigated areas, on a medium eroded calcareus chernozem, on a slope of 5^0 (8,7%). They were carried out in the period 2012-2017y., in two stages. During the first stage of the experiment, in 2012-2014y., a field experiment with grain maize with soil protection technology for minimum and unconventional soil tillage were performed applying ready compost as a mulching material. The second stage of the study was carried out between 2015y. 2017y. and during it, the soil protection technology for minimum and unconventional soil tillage for growing maize for grain was tested for agrotechnical and soil protection efficiency, using manure. To achieve the goal of the research, both stages and two field experiments were carried out by block method, in four variants with four replicates. The experiments are single factor, as the applied soil protection technologies (limiting water erosion, compaction and reduction of soil organic matter) are the factor.

The tested variants during the first stage of the experiment are:

9 th – maize plots, grown by conventional technology, applied along the slope - control;

10th - maize plots, grown by using conventional technology applied across the slope;

11th – maize plots, grown by erosion control technology, including surface mulching with ready compost, all operations applied across the slope;

12th - maize plots, grown by erosion control technology, including soil tillage without reversing the layer - loosening and soil protection operation vertical mulching with ready compost, forming slits with ducts, along with sowing and digging and furrowing along the hilling (advanced technology for minimum and unconventional soil tillage) applied across the slope.

The variants of field experiment during the second stage of the research are:

13th - maize plots, grown by conventional technology, applied along the slope - control;

14 th - maize plots, grown by using conventional technology applied across the slope;

15 th - maize plots, grown by erosion control technology, including surface mulching with manure, all operations applied across the slope;

16 th - maize plots, grown by erosion control technology, including soil tillage without reversing the layer - loosening and soil protection operation vertical mulching with manure, forming slits with ducts, along with sowing and digging and furrowing along the hilling (advanced technology for minimum unconventional soil tillage) applied across the slope.

Throughout the research period, both the two control variants, in both experimental stages (variant 9 and variant 13), are common, traditional (conventional) for this crop, and are carried out along the slope. The same conventional technological operations were also carried out in variants 10 and 14, but with the difference that their application direction is across the slope. The erosion control agro-technical measures in the other variants were applied using the methods in the following ways: surface mulching, in variants 11 and 15, was carried out before sowing across the slope by means of a fertilizer trailer 1PTU-6 (Figure 1) at the rate of 4500-5000 kg/ ha with compost mulching material in the first stage (variant 11) and with bovine manure, in the second stage - variant 15.

Fig. 1 Fertilizer trailer

In variants 12 and 16, in both stages of the experiment, included erosion control methods - loosening, vertical mulching (with compost or manure), forming slits with ducts, along with sowing and digging, and furrowing along the hilling. Loosening in this case replaces the plowing with the reversal of the soil layer. It is carried out, across the slope, at a depth of 0.40 m, with cultivator CP - 9 (Figure 2), aggregated with tractors with a nominal power of 120 to 150 kW. Vertical mulching is also carried out across the slope, before sowing with a specialized device for incorporation of organic matter into the soil (Fig. 3), by a band scheme (with interval between the slits of 0.60 m and the interval between bands 3 m in the field), at a depth of 0.40 m. However, as a mulching material, variant 12 uses ready compost, and in variant 16 this material is bovine manure. In both cases, the norm is 4500 - 5000 kg/ha, and simultaneously with this technological operation, a single disking is performed with heavy disc harrows for surface covering of slots and for preservation of soil moisture. Forming slits with ducts is done annually, twice at different times of the technological process, with different technological devices. It was applied simultaneously with the maize sowing (fig. 4), across the slope in the formed row spacing, at a depth of 0.25 m, with a distance between the slits -1.4 m.

Fig. 2 Chisel cultivator CP - 9

Fig. 3 Device for vertical mulching

Fig. 4 Sowing maize with simultaneously forming slits with ducts in soil

Along with this, the cutting with walking is carried out simultaneously with the first hoeing, in the phase of plant growth, 3-5th leaf, across the slope, at a distance of 1.4 m and a depth of 0.25 m. In this case, an inter rows device KRN - 4,2 or KOB - 4,2 is used after the hoeing machine parts (fig. 5). The other erosion control method applied in these variants (variant 12 and variant 16) – furrowing with making slits and ducts is also performed transversely to the inclination of the slopes, and in this process slitting with hilling processes are performed sequentially and simultaneously with a combined device (fig. 6).

Fig. 5 General view of cultivator and ducts KRN-4,2 with device for slits with ducts

Fig. 6 General view of device for slits forming

During the two stages of the experimental period, agro technical (soil and biometric) and erosion observations were carried out according to established methodology.

RESULTS AND DISCUSSION

The results of the comparative studies carried out with the improved soil protection technologies for minimum and unconventional soil tillage using compost or manure as a mulching material in the cultivation of grain maize on sloping arable lands, show that their application has a positive impact on agronomic and erosion indicators.

Table 1 *Bulk density (g/cm^3), total porosity(%) soil hardiness (kg/m^2) in layer 0-40 cm, experiment 2012-2014 y.*

Year, variant	Before sowing			Maximum growth stage			Harvesting		
	Bulk density	Total porosity	Hardiness	Bulk density	Total porosity	Hardiness	Bulk density	Total porosity	Hardiness
2012 y.									
9	1.26	53.51	13.34	1.30	52.03	32.82	1.32	51.29	27.41
10	1.26	53.51	13.34	1.26	53.51	31.12	1.27	53.14	24.52
11	1.26	53.51	13.34	1.24	54.24	29.57	1.24	54.24	22.34
12	1.15	57.57	10.57	1.21	55.35	25.60	1.20	55.72	21.25
2013 y.									
9	1.37	49.45	16.82	1.48	45.39	34.06	1.41	47.97	39.09
10	1.37	49.45	16.82	1.46	46.13	22.42	1.37	49.59	32.50
11	1.34	50.55	15.70	1.39	48.71	18.12	1.32	51.29	29.21
12	1.31	51.66	14.56	1.36	49.82	15.36	1.19	56.09	26.26
2014 y.									
9	1.40	48.34	14.78	1.35	50.19	18.69	1.33	50.92	25.91
10	1.40	48.34	14.78	1.34	50.55	16.21	1.32	51.29	21.89
11	1.35	50.19	11.20	1.25	53.87	11.27	1.25	53.87	19.02
12	1.32	51.29	10.10	1.20	55.72	10.45	1.14	57.93	15.18
2012-2014 y.									
9	1.34	50.55	14.98	1.38	49.08	28.52	1.*35*	50.19	30.80
10	1.34	50.55	14.98	1.35	50.19	23.25	*1.32*	51.29	26.30
11	1.32	51.29	13.41	1.29	52.40	19.65	*1.27*	53.14	23.52
12	1.26	53.51	11.74	1.26	53.51	17.14	*1.18*	56.46	20.90

ANOVA: Bulk density *p= <0.000558; HSD[0.05]=0.08; HSD[0.01]=0.1; 9vs 10 nonsignificant; 9vs 11 nonsignificant; 9vs 12 P<0.01; 10 vs 11 nonsignificant; 10 vs 12 P<0.01; 11 vs 12 nonsignificant;* ***Total porosity****: P=0.0001 HSD [0.05]=2.49; HSD[0.01]=3.13; 9vs 10 nonsignificant; 9vs 11 nonsignificant; 9vs 12 P<0.01; 10 vs 11 nonsignificant; 10 vs 12 P<0.01; 11 vs 12 nonsignificant;* ***Hardiness*** *p<0.0001; HSD [0.05]=3.62; HSD[0.01]=4.56; 9vs 10 nonsignificant; 9 vs 11 P<0.01; 9 vs 12 P<0.01; 10 vs 11P<0.05; 10 vs 12 P<0.01; 11vs 12 nonsignificant*

Table 2 *Bulk density (g/cm^3), total porosity(%) soil hardiness (kg/m^2) in layer 0-40 cm, experiment 2015-2017y.*

Year, variant	Before sowing			Maximum growth stage			Harvesting		
	Bulk density	Total porosity	Hardiness	Bulk density	Total porosity	Hardiness	Bulk density	Total porosity	Hardiness
2015									
13	1.38	49.08	16.22	1.33	50.92	34.06	1.33	50.92	23.08
14	1.38	48.08	16.22	1.30	52.03	31.21	1.31	51.66	20.84
15	1.31	51.66	10.06	1.28	52.77	26.84	1.29	52.40	18.31
16	1.21	55.35	7.76	1.17	56.83	22.20	1.25	53.87	15.37
2016									
13	1.35	50.18	16.75	1.30	52.03	17.37	1.37	49.45	44.68
14	1.35	50.18	16.75	1.28	52.77	15.62	1.30	52.03	33.63
15	1.29	52.40	15.02	1.20	55.72	13.19	1.25	53.87	28.36
16	1.23	54.61	14.40	1.18	56.46	11.20	1.18	56.46	21.49
2017									
13	1.33	50.92	14.85	1.38	49.08	25.42	1.46	46.13	34.10
14	1.32	51.29	14.41	1.36	49.82	23.20	1.43	47.23	30.25
15	1.27	53.14	13.30	1.29	52.40	19.15	1.39	48.71	27.50
16	1.22	54.98	12.80	1.26	53.51	17.21	1.32	51.29	24.33

ANOVA: Bulk density*; HSD[0.05]=0.07; HSD[0.01]=0.09;13 vs 14 NS; 13 vs 15 P<0.05; 13 vs 16 P<0.01; 14 vs 15 NS; 14 vs 16 P<0.01; 15 vs 16 NS;****Total porosity****; p=0.000703; HSD[0.05]=2.42; HSD[0.01]=3.31; 13 vs14 NS; 13 vs 15 P<0.05; 13 vs16 P<0.01; 14vs15 NS; 14 vs 16 P<0.01; 15 vs16 NS;* ***Hardiness****: p= 0.429507*

From table 1 and table 2, can be seen that values of the bulk density, total porosity and hardiness of the soil for these technologies, that include the soil protection methods, loosening, vertically mulching with ready compost or manure, making slits with ducts, along

with sowing and digging and furrowing along the hilling and in the three phases of observation and the two stages of the experiment are the best (lowest density and hardness and highest total porosity) compared to those in conventional and are almost the same as in the use of compost, and when manure is incorporated as a mulching material. In these two cases soil parameters are in optimal range (for density 1.2-1.3 g/cm^3, total porosity 50-55% and for soil hardness 15-19 kg/cm^3) for growing grain maize on slope lands (Todorov et al., 1982). This allows better development of the root system of this crop, to improve the moisture holding capacity, the nutrient and air regime of the soil.

Lower but relatively good soil indicators are also found in the application of the second soil protection technology, including the soil protection measure surface mulching at both stages of the study, the first one using compost and the second - with manure (variant 11 and variant 15).

Similar are the results from the observations of the height of the plants (table 3 and table 4), their leaf surface (table 5 and table 6), as well as the average yields of grain maize (table 7 and table 8).

Table 3 *Height of plants by phases of development (cm) maize experiment 2012-2014y.*

Variant	Phase of development			Phase of development			Phase of development			Phase of development		
	5th leaf	9th leaf	Tessel development	5th leaf	9th leaf	Tessel development	5th leaf	9th leaf	Tessel development	5th leaf	9th leaf	Tessel development
	2012y.			2013y.			2014y.			2012-2014y.		
9	21,23	90,50	170,67	22,50	125,00	220,10	36,40	95,33	237,10	26,71	103,61	209,29
10	23,76	110,46	172,50	23,70	152,30	227,50	42,80	102,20	256,25	30,09	121,65	218,75
11	26,28	123,38	193,00	27,20	161,10	231,60	49,40	117,40	260,30	34,29	133,96	228,30
12	34,51	141,90	213,33	34,40	166,50	243,50	50,60	134,50	270,00	39,84	147,63	242,28

***ANOVA (tessel development)**: NS*

Table 4 *Height of plants by phases of development (cm) wheat experiment 2015-2017y.*

Variant	Phase of development			Phase of development			Phase of development			Phase of development		
	5th leaf	9th leaf	Tessel development	5th leaf	9th leaf	Tessel development	5th leaf	9th leaf	Tessel development	5th leaf	9th leaf	Tessel development
	2015y.			2016y.			2017y.			2015-2017 y.		
13	18,50	91,00	207,60	25,60	84,10	200,60	23.30	82.20	200.00	22.47	85.77	202.73
14	24,50	103,10	213,00	41,00	98,00	234,00	23.60	89.30	204.00	29.70	96.80	217.00
15	29,40	120,40	259,00	44,40	113,80	250,00	37.16	108.50	240.00	36.99	114.23	249.67
16	33,80	136,30	273,38	50,00	116,00	276,50	44.00	110.10	265.00	42.60	120.80	271.63

***ANOVA (tessel development)**: p<0.0001;HSD[0.05]=25.54; HSD[0.01]=34.92; 13 vs 14 NS; 13 vs 15 P<0.01; 13 vs16; p<0.01; 14 vs 15 P<0.05; 14 vs 16 P<0.01; 15 vs 16 NS*

Table 5 *Leaf area by phases of crop development (m^2/ha), experiment 2012-2014y.*

Variant	Phase of development			Phase of development			Phase of development			Phase of development		
	5th leaf	9th leaf	Tessel development	5th leaf	9th leaf	Tessel development	5th leaf	9th leaf	Tessel development	5th leaf	9th leaf	Tessel development
	2012y.			2013y.			2014y.			2012-2014y.		
9	239,85	831,55	16351,80	298,20	966,10	18660,50	294,85	1065,34	24999,10	277,63	954,33	19970,47
10	280,58	1341,20	17719,67	355,40	1291,40	19013,10	311,90	1315,83	24392,50	315,96	1316,14	20375,09
11	426,29	1714,40	21406,92	487,60	1813,30	23950,30	494,63	1667,17	25704,60	469,51	1731,62	23687,27
12	477,91	2011,39	23969,39	508,10	2140,10	26515,20	640,72	2205,94	29424,90	542,26	2119,21	26575,83

ANOVA: p=0.123614

***Table 6** Leaf area by phases of crop development (m^2/ha), experiment 2015-2017y.*

Variant	Phase of development			Phase of development			Phase of development			Phase of development		
	5th leaf	9th leaf	Tessel development	5th leaf	9th leaf	Tessel development	5th leaf	9th leaf	Tessel development	5th leaf	9th leaf	Tessel development
	2015y.			2016y.			2017y.			2015-2017 y.		
13	200,83	1172,20	14899,10	179,06	951,01	20709,94	170,16	935,10	20150,18	183,35	1019,37	18586,41
14	290,91	1506,60	16064,70	201,91	1243,02	22768,60	175,25	1072,20	21576,37	222,69	1273,94	20136,56
15	433,86	1792,40	24452,60	318,50	1808,68	24904,26	298,60	1719,32	23890,14	350,32	1773,47	24415,67
16	530,32	2344,40	25142,70	463,33	2166,02	29850,86	315,53	2080,25	28972,63	436,39	2196,89	27988,73

***ANOVA(tessel development)**; p=0.010963; HSD[0.05]=7128.12; HSD[0.01]=9744.2; 13 vs 14 NS; 13 vs 15; NS; 13vs16 P<0.05; 14 vs 15 NS; 14 vs 16 P<0.05; 15 vs 16 NS*

The height of plants and their leaf area, on average over the period of the study, are again with the highest values, with the application of the advanced soil protection technology for minimum and unconventional soil tillage (vertical mulching) in the three phases of plant development - 5^{th}, 9^{th} leaf and forming a panicle. By comparing these indices, during the two stages of the experiment using compost or manure as a mulching material (variant 12 and variant 16) that the values of these two parameters in all three phases of development are similar to the slight prevalence of those in which manure is involved as mulch - variant 16. The same is also observed with the use of soil protection technology including the erosion control method with surface mulching with manure (variant 15), although at her application the plant heights and leaf surfaces are smaller than those of vertical mulching.

***Table 7** Grain yield at 14% humidity, 2012-2014y.*

Year, variant	Yield		Yield		Yield		Yield	
	kg/ha	%	kg/ha	%	kg/ha	%	kg/ha	%
	2012		2013		2014		2012-2014	
9	2885,0	100,0	6753,0	100,0	7067,0	100,0	5568,33	100,0
10	3182,0	110,3	7098,0	105,1	7421,0	105,0	5900,33	106,0
11	3274,0	113,5	7328,0	109,3	7648,0	108,2	6083,33	109,3
12	3443,0	119,3	7937,0	117,5	8264,0	116,9	6548,00	117,6
GD5%	114.0	3.10	203.0	3.01	33.47	0.47		
GD1%	158.0	4.30	307.0	4.30	50.71	0.68		
GD0,1%	216.0	5.80	494.0	6.70	81.52	1.07		

***Table 8** Grain yield at 14% humidity, 2015-2017 y.*

Year, variant	Yeild		Yeild		Yeild		Yeild	
	kg/ha	%	kg/ha	%	kg/ha	%	kg/ha	%
	2015y.		2016y.		2017y.		2015-2017 y.	
13	7158	100,0	6165	100,0	5723	100,0	6348,67	100,0
14	7513	104,9	6526	105,9	6041	105,6	6693,33	105,4
15	7840	109,5	6737	109,3	6326	110,5	6967,67	109,8
16	8387	117,2	7096	115,1	6677	116,7	7386,67	116,4
GD5%	18.96	5.56	27.14	7.96	3.83	1.12		
GD1%	27.23	7.62	39.00	10.91	4.50	1.54		
GD0,1%	40.06	10.75	57.37	15.40	8.09	2.17		

This gradation of variants in their agro-technical efficiency, as shown in table 7 and table 8, is also maintained taking into account the average yields of corn grain. The highest is the average yield of the variants using the advanced soil protection technology during both stages of the experiment (variant 12 and variant 16). In the period 2012-2014y., the average yield of grain in variant 12, with application of compost as mulching material was 979.7 kg/ha (with 17.6%) higher than that of conventionally grown crop, along the slope (the control variant 9) with 647.7 kg/ha (with 11.0%) higher than that of the variant conventionally grown across the the slope and with 464.7 kg/ha (with 7.6%) higher than that of plots grown with soil protection technology, including surface mulching with ready compost. In the second stage of the survey (2015-2017y.), these yield data are similar, with the average maize yield in variant 16 using the vertical mulching method with manure is with 1038 kg/ha (with 16.4%) higher than that of the conventionally grown control, variant 13, with 693.3 kg/ha (with 10.4%) higher than the crop grown across the slope - variant 14 and 419 kg/ha (6.0%) higher than that of variant 15 grown with soil protection technology including surface mulching with manure.

Comparison of these results for yields shows that in these indicators values are highest and at the same time very close, in variants using advanced technology for minimum unconventional soil tillage, including vertical mulching with ready compost or manure (variant 12 and variant 16) with slight preponderance, again with the application of manure as a mulching material.

These technologies in both variants (with the compost or manure, as a mulch), when growing corn for grain on slopes, have a higher erosion control effect as compared with other examined technologies, in both stages of the experiment (table 9 and table 10 as well as fig. 7 and 8). This, according to Dimitrov (2016), is due to increased water permeability of soil and improved soil protection effect of vegetation and organic residues, reflecting both the volume of runoff and the amount of the eroded soil.

Table 9 *Total volume of surface water runoff and amount of eroded soil 2012-2014 y.*

Date	Rain l/m^2	Surface water runoff m^3/ha				Eroded soil kg/ha			
		Variant				Variant			
		9	10	11	12	9	10	11	12
28.05.12	22.0	225.252	123.630	116.768	43.960	3622.0	1446.8	1378.0	168.5
06.08.12	15.5	141.907	73.913	70.909	26.733	1927.8	682.2	655.9	83.9
12.08.12	18.0	174.820	93.762	90.101	33.664	2598.6	981.4	939.0	116.5
27.08.12	12.5	128.957	65.217	62.828	23.960	1855.0	648.1	617.9	76.4
For 2012 y.	68.0	670.936	356.522	340.606	128.317	10003.4	3758.5	3590.8	445.3
12.06.13	28.0	182.113	105.763	95.932	35.140	2660.0	1014.9	937.1	117.2
13.06.13	12.0	157.183	89.492	79.661	29.533	2054.1	744.2	669.8	88.8
08.07.13	28.5	190.775	114.509	102.203	37.570	2899.1	1116.9	1044.1	128.6
For 2013 y.	68.5	530.071	309.764	277.796	102.243	7613.2	2876.0	2651.0	334.6
14.05.14	18.0	230.365	141.151	127.135	45.236	3260.2	1293.8	1185.6	145.3
31.05.14	54.0	165.547	93.237	83.027	31.099	2112.9	771.1	699.5	92.1
18.06.14	30.0	200.548	117.410	104.432	39.267	3102.5	1188.9	1104.2	136.2
For 2014y.	102.0	596.496	351.798	314.594	115.602	8475.6	3253.8	2989.3	373.6
Average 2012-2014 y.	79.50	642.153	370.615	310.999	115.387	8697.3	3296.1	3077.0	384.5

ANOVA Surface water runoff*; P<0.0001; HSD[0.05]=27.62; HSD[0.01]=34.26; 9 vs 10 P<.01;9 vs d11 P<.01;9 vs 12 P<.01;10vs 11 nonsignificant; 10 vs 12 P<.01;11 vs 12 P<.01;* ***Eroded soil****:P<0,0001; HSD[.05]=433.71; HSD[.01]=537.98; 9 vs 10 P<.01; 9 vs d11 P<.01;9 vs 12 P<.01;10vs 11 nonsignificant; 10 vs 12 P<.01;11 vs 12 P<.01*

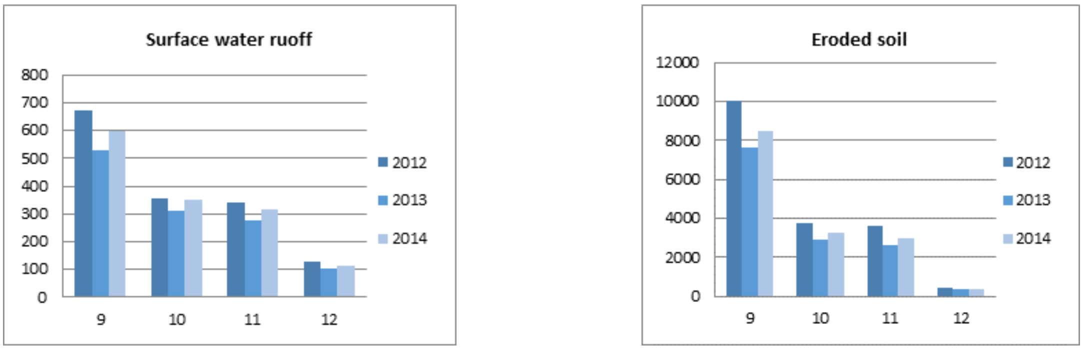

Fig. 7 Erosion control efficiency of the applied technologies for soil tillage, maize experiment, for the period 2012-2014y.

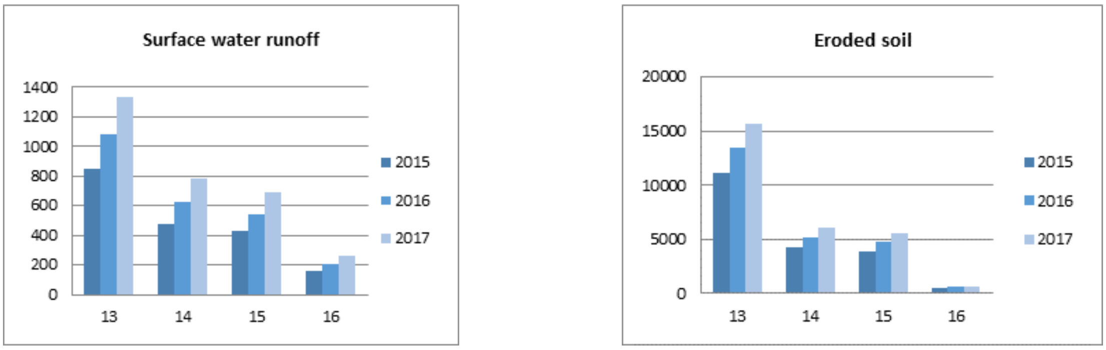

Fig. 8 Erosion control efficiency of the applied technologies for soil tillage, maize experiment, for the period 2015-2017 y.

Table 10 *Total volume of surface water runoff and amount of eroded soil 2015-2017y.*

Date	Rain l/m^2	Surface water runoff m^3/ha				Eroded soil kg/ha			
		Variant				Variant			
		13	14	15	16	13	14	15	16
26.05.15	16,0	266,426	154,983	142.614	51.378	3758.7	1501.6	1375.1	167.0
10.06.15	18,0	226,137	124,068	112.705	42.581	2879.9	1094.9	982.9	125.3
02.07.15	14,5	201,227	110,034	97.933	37.478	2517.8	939.5	843.6	109.3
21.08.15	51,0	154,224	83,797	74.407	28.856	1930.7	704.3	624.8	84.3
For 2015 y.	99,5	848,014	472,882	427.659	160.293	11087.1	4240.3	3826.4	485.9
05.05.16	20.0	265.263	159.468	140.964	52.023	3457.1	1375.7	1263.5	156.2
24.05.16	16.0	233.263	137.143	120.722	44.740	2920.0	1140.4	1050.0	129.7
06.06.16	12.0	174.737	98.073	84.217	32.601	2139.5	795.8	736.4	93.4
12.06.16	18.0	224.842	133.555	115.663	42.948	2802.0	1063.3	983.8	123.8
11.08.16	15.0	181.053	101.262	83.133	32.948	2192.2	812.8	727.1	95.4
For 2016 y.	81.0	1079.16	629.501	544.699	204.624	13510.8	5188.0	4760.8	598.5
06.05.17	20.2	255.582	149.591	133.060	50.269	3116.7	1240.6	1162.8	140.1
27.05.17	13.0	168.435	99.785	88.198	32.618	2017.7	748.2	697.6	89.0
19.06.17	11.0	170.149	95.054	85.230	31.812	2039.6	756.3	705.7	89.7
02.07.17	32.0	261.940	153.979	137.809	51.544	2960.6	1136.9	1059.6	133.4
13.08.17	18.0	220.299	129.462	114.912	41.477	2692.2	1036.7	925.9	119.2
03.09.17	42.0	256.567	153.979	134.841	50.336	2885.9	1118.3	1030.4	130.0
For 2017 y.	136.2	1332.97	781.850	694.050	258.056	15712.7	6037.0	5582.0	701.4

ANOVA Surface water runoff *HSD[0.05]=420.41; HSD[0.01]=574.7;13 vs 14 P<0.05; 13 vs 15 P<0.05; 13 vs 16 P<0.01; 14 vs 15 NS; 14vs16 P<0.05; 15 vs 16 NS;* ***ANOVA Eroded soil****: HSD[0.05]=3453.12; HSD[0.01]=4720.44; 13 vs 14 P<0.01; 13vs 15 P<0.01; 13 vs 16 P<0.01; 14 vs15 NS; 14 vs 16 P<0.05; 15 vs16 P<0.05*

The data on table 9 and figure 7 show that during the first stage of the study, in the period 2012-2014 y., the use of the advanced soil protection technology, with vertical mulching with manure, including the methods of loosening, making slits with ducts, along with sowing and digging and furrowing along the hilling, the average of annual surface water runoff decreases from 5.2 to 5.4 times and those of the eroded soil from 21.5 times to 24.3

times compared to maize grown conventionally along the slope - control variant 9. During the second stage of the experiment (2015-2017y.), the use of advanced soil protection technology, including the methods of loosening, vertically mulching with manure, making slits with ducts, along with sowing and digging and furrowing along simultaneously the hilling of maize, as can be seen from the table 10 and fig. 8, this decrease in surface water runoff is almost the same as in the first stage of 5.1 to 5.5 times, and in the quantity of eroded soil is from 22.2 to 23.1 times, compared to the control – variant 13.

A lower erosion control effect was observed in variants 11 and 15 with the application of the soil-protection technology using the surface mulching method with compost or manure. Using this technology, during the first stage of the experiment, when the mulching material was compost, the reduction of the surface water runoff is 1.9 to 2.1 times, and the quantity of eroded soil is up to 3.0 times lower as compared to the control, variant 9 (fig. 7). This reduction in surface runoff and soil loss compared to the control variant 13 during the second stage of the research using surface mulching with manure is 1.9 to 2.2 times for water runoff and 2,7 to 3.1 times for the eroded soil (fig. 8).

CONCLUSION

Taking into consideration the results of the comparative study of the improved soil protection technologies for minimum and unconventional tillage of the soil by application of the erosion control method vertical mulching with different mulching materials, as well as soil protection technologies with application of surface mulching with these materials for growing wheat on sloping agricultural lands, we can draw the following conclusions:

1. The two advanced soil protection advanced technology for minimum and unconventional soil tillage for growing grain maize on inclined terrains including the erosion control method vertical mulching with ready compost and vertical mulching with manure, as well as the loosening methods as main tillage, making slits with ducts, along with sowing and digging, and furrowing along the hilling in the maize, in the conditions of chernozem are applicable in the Republic of Bulgaria and reliable means to protect the soil from degradation processes - erosion, compaction and loss of soil organic matter on slope farmlands with inclination 5 ° (8.7%).

2. Application of advanced soil protection technologies for cultivation of grain maize on slope arable lands, in both variants including erosion control methods, vertical mulching with compost, loosening, making slits with ducts, along with sowing and digging and furrowing along the hilling the first variant and the loosening, vertically mulching with manure, loosening, making slits with ducts, along with sowing and digging and furrowing along the hilling in the second, help obtaining and maintaining a soil density, hardness and total porosity close to the most favorable for the development and growth of that crop, as evidenced by the highest levels of the biometric indices and the higher average grain yield of maize. In the first variant using compost as a mulching material, it is 979.7 kg/ha (17.6%) higher compared to the conventional technology applied along the slope, and in the second variant using of manure for mulch, this increase is slightly higher with 1038 kg/ha (16.4%) compare to the control.

3. The runoff and erosion control efficiency of advanced soil protection technologies for growing corn on sloping terrains in both variants of work using compost and manure as a mulch material are higher than those of conventionally used technology in this agricultural crop cultivation. In their application, in the first variant of experiments, the values of the surface water runoff decrease from 5.2 to 5.4 times and those of the eroded soil from 21.5 to 24.3 times, compared to the conventionally grown plots along the slope. In the second variant, this reduction is almost the same as in the surface water runoff of 5.1 to 5.5 times, and in the eroded soil it is from 22.2 to 23.1 times, compared to the control.

4. The application of the two soil-protection technologies for growing maize for grain on sloping areas using the surface erosion control method of the first experiment with compost for surface mulching and with bovine manure in the second period of research, also have a relatively good soil protection role. Both mulching materials used, reduce surface water runoff to 2.1-2.2 times and eroded soil to 3.0-3.1 times the control. They also contribute to an increase in average maize grain yield of 515.0 kg/ha (9.3%), compared to conventionally grown crop along the slope, in the first soil protection technology, and in the second with 619.0 kg/ha (9.8%).

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Measuring Produced Biogas Using Kinect Device

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Abstract: *This article deals with automated measurements of produced biogas. In the National reference laboratory of biogas transformations, values are recorded manually into dairies, which are then archived and manually transcribed into a digital form. MS EXCEL, from which necessary charts are generated, is among the most widely used programs for that. The main objective of this paper is to develop automation solutions to this problem. The MS Kinect motion sensor was used for research and creating this application. This device was originally designed for applications that are controlled by motion. However, they can also be used just for taking individual pictures. Using this device, a picture of small biogas reactor is taken and then it is automatically processed using our software. The result is a digital record of the amount of the produced biogas. These values are then stored in an internal database, which can be accessed in real time using a VPN (virtual private network).*

Keywords: Biogas station, kinect, automatic measuring, image recognition.

INTRODUCTION

Nowadays, the production of biogas is on the increase. Its use can be found mainly as a source of the production of electricity or the production of heat. Biogas is produced through anaerobic digestion, a complex of consecutive microbial processes [1]. It is very important to regularly monitor and check this process of fermentation to ensure the best possible conditions for microbial community. This allows us to reach the highest possible values of the biogas produced in the highest quality, which is also continuously looked into in our workplace [2].

At present, values are recorded into diaries in the National reference laboratory of biogas transformations (located at Mendel University in Brno) which are then again manually transcribed into a digital form (MS EXCEL) and after that archived. The disadvantages of the current situation are: a) the impossibility of online check of the biogas production b) complicated check of the correctness of the transcription c) impossibility to measure with the frequency of more than once a day (from personnel reasons). The proposed solution will enable us to measure the data continuously in the intervals which will be set in advance. This fact enables not only more frequent data readings, but also more frequent check of the measured data. It will be possible to access the measured data in real time and in case of finding an error, it will be possible to respond immediately. Since the data are stored online, they can also be directly processed and evaluated. This allows us to avoid human error during processing, for instance, because of inattention.

The data readings take place using the Kinect device by Microsoft. This device was originally designed for motion control but it enables us to take individual pictures as well (instead of video) and then to edit them. VisualStudio 2015 was used to create the application. C++ was chosen as the main programming language, not only for its compatibility, but also because of the number of already created applications and existing online support.

MATERIAL AND METHODS

Used hardware

The Kinect Device by Microsoft was used as a device for image sensing. This device was originally designed to be used as a motion control device for Xbox 360 video game console. However, compatibility with PC and USB port for connecting to the PC were added. Even though Kinect offers a whole range of options for image sensing, we will use it as a common webcam mainly because of easy interchange ability with other devices (for example a common webcam). When using Kinect, a wide range of options to improve the current system in the future opens up. On Fig. 1, we can see a diagram of the measurement system.

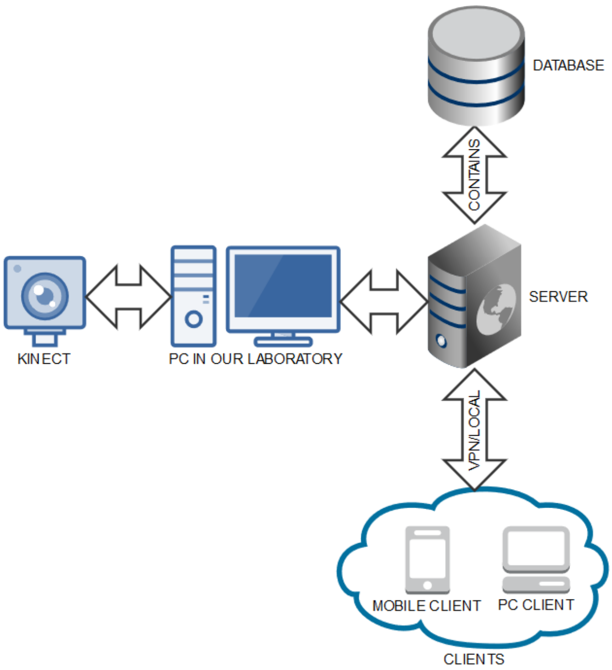

Fig. 1 Wiring diagram used system components

Kinect and PC

Kinect enables us to capture in two main modes (Fig. 2).The sensor has an angular field of view of 43° vertically and 57° horizontally. The horizontal field of the Kinect sensor at the minimum viewing distance is 87 cm, and the vertical field is 63 cm. At the given resolution of the depth camera, it can be easily calculated that one image pixel accounts for only 1.3 mm of the sensing area.

The accuracy decreases with the increasing distance of the object from our sensor. For better illustration, Fig. 2 shows maximum and minimum possible distances while maintaining accuracy. It is also necessary to take into account whether the sensor works in the mode of the standard or decreased distance. The mode of the decreased distance was added at newer models, which were designed primarily for PC.

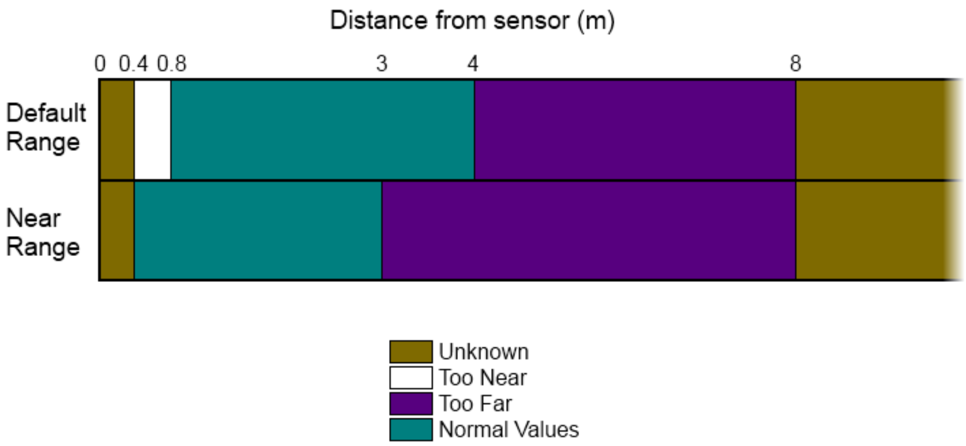

Fig. 2 Kinect sensor distance – taken from www.msdn.microsoft.com

For the received data processing, a standard personal computer placed in a biogas laboratory with OS Windows 8.1 was used.

Database

For data storing is used MS SQL Server. On Fig. 3, we can see database ERD diagram.

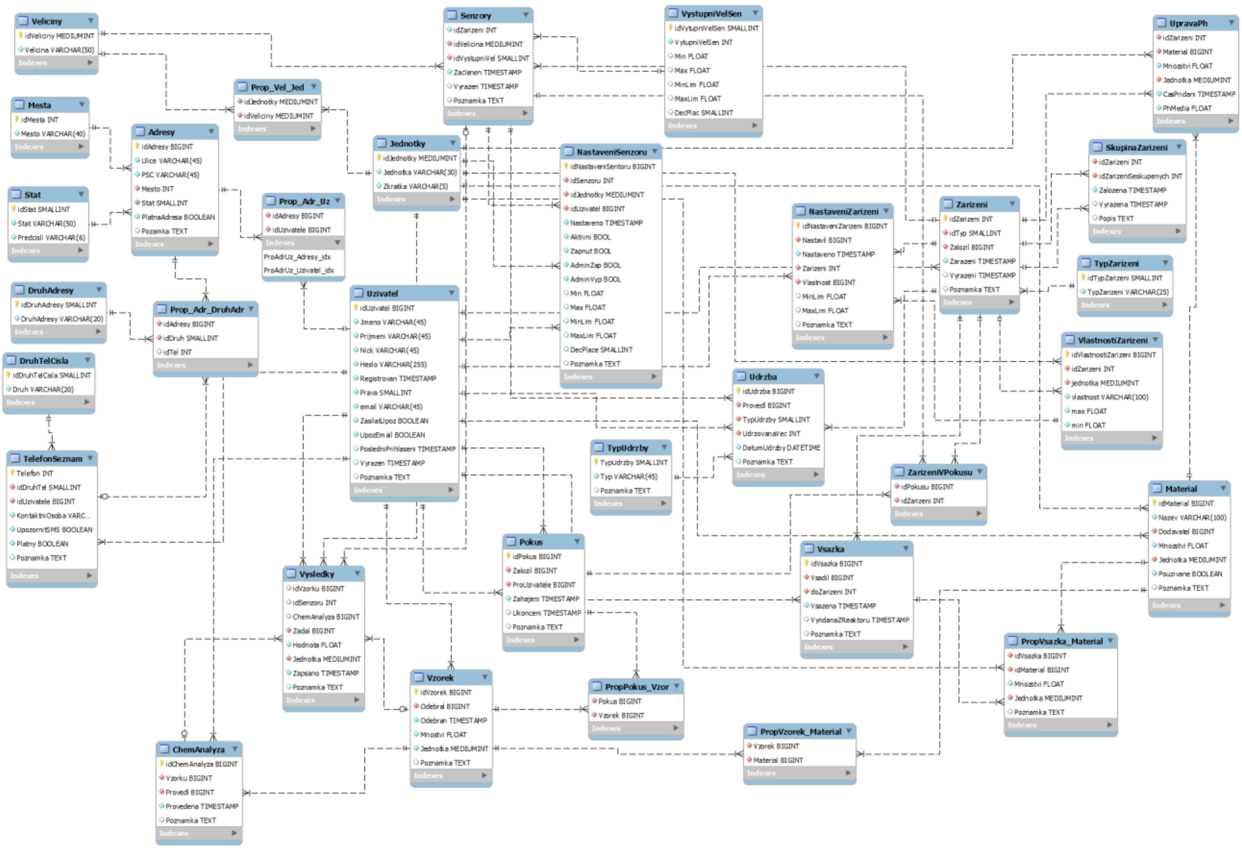

Fig. 3 Database ERD diagram

Used software

VisualStudio 2015, development environment by Microsoft, was used to create our application. It can be used to develop console applications and applications with graphical interface along with Windows Form applications, websites, web applications and services.

VisualStudio supports programming languages through language services, allowing code editor and debugger to support any programming language. The embedded languages include C / C ++ (using Visual C ++), VB.NET and C#. Support of other languages such as for example Python, Ruby, etc. can be added using the language services.

C++, or visual C++ integrated in VisualStudio, was selected as the default programming language for creating our application. It is a multi-paradigm programming language, which was an extension of C language. Whereas C was a purely procedural language, C++ is formed as an object oriented language. The idea of OOP (object-oriented programming) is in the proposal of data classes which describe a certain set of properties and how to deal with them. Nowadays, this language is among the most widely spread programming languages.

To work with images, OpenCV(Open Computer Vision) was used. It is an open source set of libraries for working with real time computer vision. It is possible to develop and create applications for gesture and faces recognition, object identification and so on. It is therefore used mainly in robotics and for the implementation of applications in experimental interfaces for human-computer interaction (Human-Computer Interaction), etc. OpenCV is associated with Intel Company which implements its support directly to hardware – it uses Intel Integrated Performance Primitives technology which provides high performance for low-level routines (audio, video, speech recognition, coding, decoding and cryptography).

This library is very robust because it includes tools for a complete analysis of the image

(image filtering, object detection, motion analysis, image transformation, working with video, simple work with windows and user interface, camera calibration, support for stereo – involvement of multiple cameras), etc. Multiplatform is an advantage. This framework exists in versions for GNU/LINUX, Microsoft Windows and MAC OS X. A continuous development is another advantage. The library is still being worked on. The last version of OpenCV, which is also used for creating our application, was released in December 2015.

RESULTS AND DISCUSSION

It was necessary to additionally edit the photo after taking it, especially clip it down to a certain size. The next step was to detect the correct height level (Fig. 3) in the correct biogas reactor. Reactors are always marked with numbers in their upper part. Identifying a correct reactor is done through image recognition using the MatchTemplate method. A draft of the algorithm will be submitted (in our case the marker with number 9) and using the algorithm, we try to search the image and correctly detect the template.

After detecting the correct cylinder, we will draw in detail the height level (filled rectangle in Fig. 3) and using the algorithm for filling the cylinder we will fill it with a pre-defined colour, in our case black. In the following step, the image is converted into black and white using the method of thresholding (it can be seen in Fig. 3 as well). This step is important mainly because of determining the number of pixels, which needed to be coloured to fill the cylinder from its peak to the level. Our control cylinder is formed by a rectangle with a side A = 20 pixels and side B = 697 pixels. Thanks to thresholding and conversion to black and white (black colour in our cylinder determines the height level) and using algorithm for searching in the field (our picture in the internal memory is represented as a field of values where each field contains information about RGB model, that is red, green and blue) we can easily count the number of black pixels in the vertical direction. In our case it is 134 pixels. One pixel in our picture has a value of 0.86 mm. The level dropped by 115 mm.

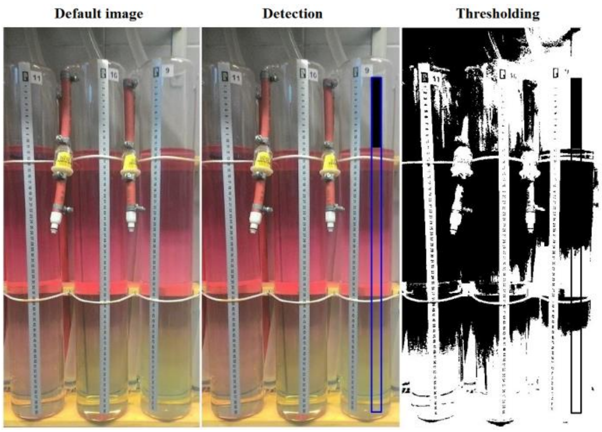

Fig. 4 Image processing and determining the height level

If the final height level is known, we can calculate the volume of produced biogas using the following equation:

$$V_n = \frac{T_0}{T_n} \cdot (k \cdot h_n) \cdot \frac{\left[\left(p_a + (h_k \cdot \rho \cdot g) + \left(\left(\frac{h_n}{100}\right) \cdot \rho \cdot g\right)\right)\right]}{p_a} \cdot 10^{-3} \text{ [m3]} \quad (1)$$

Description of individual members of the equation (1) is shown in Table. 1.

Table 1 *The meaning of constants mentioned in the above equation*

Constant	Meaning	Unit
V_n	the volume of biogas at physically normal conditions	[m^3]
T_0	physically normal thermodynamic temperature	[K]
T_n	measured thermodynamic temperature	[K]
K	calibration constant of the measurement system	[-]
h_n	height levels	[cm]
Pa	atmospheric pressure	[Pa]
h_k	height constant of measured distance	[m]
ρ	the density of the fluid reservoir	[kg/m^3]
g	acceleration of gravity	[m/s^2]

Measured values are now stored in database. Database structure was described in previous chapter.

In Fig. 5 we can see the comparison between the direct measurement and the values obtained using Kinect. Measured values are indicated in cm.

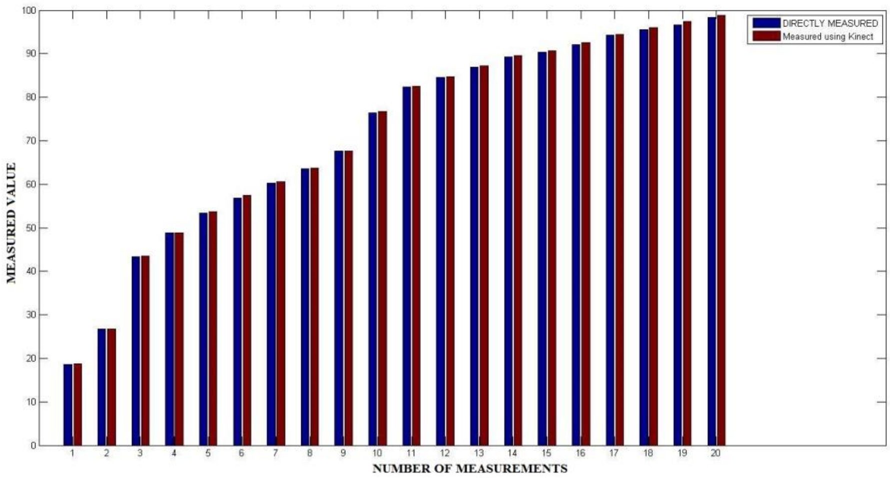

Fig. 4 Comparison between the direct measurement and the values obtained using Kinect

Nowadays, the development of applications for image recognition is widespread. Such applications are used for example for face recognition [2]. The image recognition is also used a lot in automobile industry where the aim of the system is to recognize licence plates of particular cars [3]. This is used for example for the search for a specific vehicle due to theft. Recently, image recognition has been shifted towards mobile devices. It is also for example because of still expanding augmented reality [4]. It is therefore obvious that image recognition is nowadays a widespread issue and in some fields it is a must.

On the contrary, our solution for reading of the values of produced biogas is very specific, mainly because of specific solution of biogas reactors inside the National reference laboratory of biogas transformations. Another important fact is that the above mentioned techniques are used mainly for object recognition, not for readings of values.

CONCLUSION

Automation of measuring of the produced biogas in small bioreactors was carried out. The main advantages include more accurate measurements and ensuring continuous measurement at given intervals – including weekends and holidays. Nowadays, the values are recorded manually into diaries, which are then archived. Currently, the resulting values are manually written in the equation. The possibility of errors in calculation will also be decreased with the introduction of the automated system.

Another undeniable advantage is that in case of the data export to a pre-prepared database, the results can be accessed anywhere on the internet after the user validation. It also give us an option of export in the data from the database using a pre-specified key (for example the date, the volume of produced biogas, used batch, etc.).

Our laboratory solution is very specific, for this reason it is hard to compare it with other solutions of biogas measuring. In industrial solution, biogas production is measured by certified gas meters. From this reason it is hard to find other articles on this subject from other authors.

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The Impact of Network Capacity on Quality of Communication Infrastructure for Intelligent Agriculture

Petr Koudelka, Jan Marecek, Vlastimil Slany, Pavol Findura, Miroslav Pristavka

Abstract: *The technological drafts and systems belonging to intelligent agriculture category are based on the utilization of information and communication technologies. On 25 November 2015, Regulation (EU) 2015/2021 of the European Parliament and of the Council laying down measures concerning access to the open internet access came into force. This Regulation aims to establish common rules to safeguard equal and non-discriminatory treatment of traffic in the measures of internet access services and related end-user's rights. Open internet access (network neutrality) is the foundation for Intelligent Agriculture services. Based on the general mathematical model of the access network and practical experiences from real network traffic it turns out that to the current method need to add the measurement of qualitative parameters according to ITU-T Y.1564 standard. The results of this complex method allow to indicate an insufficient capacity of the distribution network and other anomalies in the access network which could do a creation of discrepancy or even an unavailability of internet access service, respectively intelligent agriculture service. The article is focused the issue of the impact of QoS parameters on the compliance with network neutrality.*

Keywords: *network capacity, intelligent agriculture, quality of communication infrastructure, communication infrastructure*

INTRODUCTION

On 25 November 2015, Regulation (EU) 2015/2021 of the European Parliament and of the Council laying down measures concerning access to the open internet access came into force [1]. In its statement about network neutrality, Czech Telecommunication Office ("CTO") generally defined four data parameters in the form of transmission speeds of both directions (upload, download). These parameters must be part of the contracts of service providing, including impact of discrepancy as indicators of the fact that the performance of the service doesn't achieved agree parameters. CTO has established a method of inspection existence of discrepancy as indicators of the fact that the performance of internet access service doesn't achieved agree parameters or unavailability of service itself, according to the method based on IETF RFC 6349, [2]. In special situations, for example in case of dedicated lines or in case of measurement on the demarcation points DeP < 6 is possible to use methods based on ITU-T Y.1564 standard, see Fig. 1, [3]. Practical experience of the CTO from real measurements of access networks point out that the very problematic phenomenon of the present is the insufficient capacity of the distribution network, eventually access network [4].

General Behaviour of the Distribution Network

The general model of the internet access service behavior can be based on the general model of the structure of the access network and its connection to the internet as defined by the CTO in its updated methodology for measuring and evaluating data parameters of fixed and fixed wireless access, see Fig. 1. We mark the capacity of a distribution network which ensuring connectivity for access points, by the parameter μ and the other parameter $\mathcal{N}$ marks a set of content providers (CP_s), whose services (not only based on the intelligent agriculture technologies), are used by end-users of an internet service providers (ISPs), [7]. The mark m_i denote a group (count) of end-users (intelligent agriculture services) for every $CP_i = \mathcal{N}$. We can define $\theta_i \triangleq m_i\lambda_i$ in a form of required data throughput of a Content Provider service, where λ_i is the average data throughput per end user. The total required data throughput of a distribution network may be written as:

$$\phi \triangleq \sum_{k\in\mathcal{N}} \theta_k \tag{1}$$

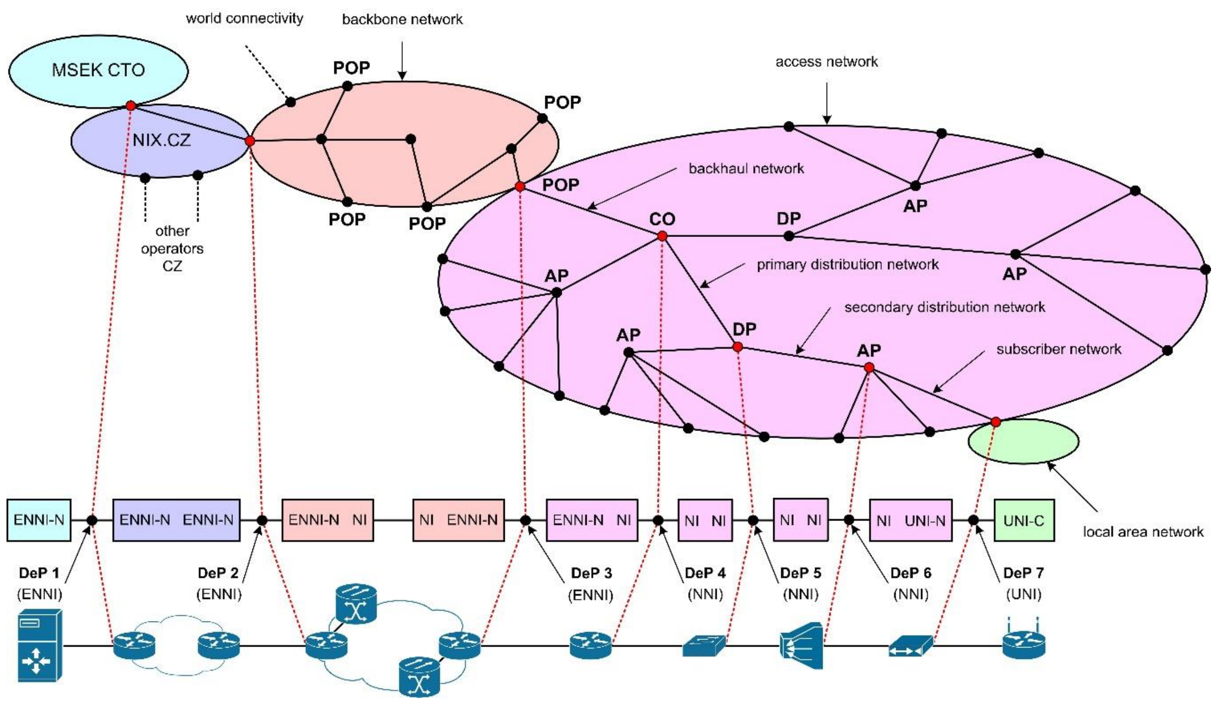

Fig. 1 General model of structure of access network and its connection to the internet

We can define the system usage of the distribution network as a function of μ and θ , if we know the capacity of the distribution network μ and the required data throughput θ :

$$\phi \triangleq \Phi(\theta, \mu). \tag{2}$$

Assuming knowledge of an average data throughput of the end user λ_i , we can write the function of system use of distribution networks in the form of:

$$\lambda_i = \lambda_i(\phi). \tag{3}$$

Denote the end users using the services of content providers in the form of the vector $\overrightarrow{m}$. Fig. 2 shows a general model of distribution network behavior ($\overrightarrow{m}$; μ) where the end user vector $\overrightarrow{m}$ and the distribution network capacity together determine the system utilization of the distribution network ϕ a and for each of the content providers CP_i the required data throughput θ_i. Since the system utilization of ϕ has an increasing character due to the required data throughput θ_i. Since the system utilization of ϕ has an increasing character due to the required data throughput θ_i, which with the increasing system utilization, approaching the overload status, is declining, the resulting system utilization of the distribution network should be in balance. We can thus write that ϕ is a system utilization of the distribution network ($\overrightarrow{m}$; μ), if the following conditions are met:

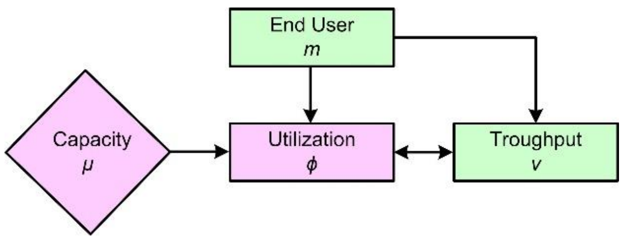

Fig. 2 General model of distribution network behavior

$$\phi = \Phi\left(\sum_{k\in\mathcal{N}} m_k\lambda_k(\phi), \mu\right). \quad (4)$$

Fixed Wireless Access and IoT

Fixed Wireless Access (FWA) test technology, which includes the widely used Wi-Fi technology (IEEE 802.11n, IEEE 802.11ac) in the Czech Republic, has also been included in the group of fixed electronic communications networks, as well as in recent years a popular way to connect via mobile service technology at a fixed location (LTE 3.9G, LTEAdvanced 4G mobile network). In 2015, 20.2 PB of data were transmitted via the mobile service at a fixed location in the Czech Republic, 37.23 PB of data in 2016 and 88.9 PB of data in 2017. This is more than a five-fold increase compared to 2015. When we compare the total volume of data transferred on mobile networks with the transferred data volume only within the mobile service at a fixed location, we find that the key service accounts for 48.6 percent of the total data volume, which is the proportion and impact of this service on the overall quality of the Internet access service.

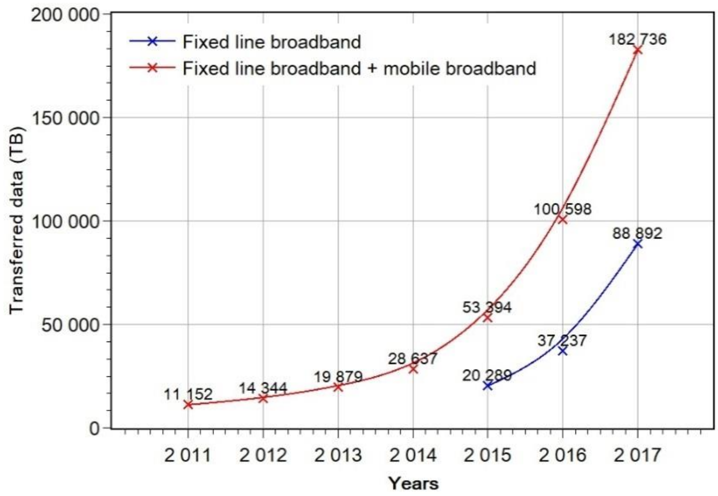

Fig. 3 The total volume of data transferred on mobile networks

Due to the dynamic increase in the number of mobile networks, the assumption was made as to the extent to which the capacities of the distribution and connection networks μ for the general development of services belonging to the intelligent agriculture set of technologies, which undoubtedly will bring significant additional system load Φ . Example is general development of services belonging to the intelligent agriculture set of technologies, which will undoubtedly bring significant additional system load:

– Minimum speed $R_{\min\left(\frac{up}{down}\right)} = \frac{16}{16}\mathbf{kb/s}$.

– Maximum speed $R_{\max\left(\frac{up}{down}\right)} = \frac{2.0}{20}\mathbf{Mb/s}$.

– Normally available speed $BDR\left(\frac{up}{down}\right) = \frac{1.6}{16}\mathbf{Mb/s}$.

Measurements were made off-peak (t_0 = 08:00:00), in the afternoon at the beginning of the peake (t_0 = 14:00:00) and in the evenings during the peak (t_0 = 20:45:00). Fig. 4 shows the measurement results according to the CTO methodological procedures in accordance with Regulation (EU) 2015/2120. From the measured values TCP $\mathbf{aTR_{down}}$ data drop below the defined DZV threshold is noticeable. It is obvious that in the afternoon there was a large repetitive deviation from the currently available speed, even in the even hours a very long deviation from the normally available speed.

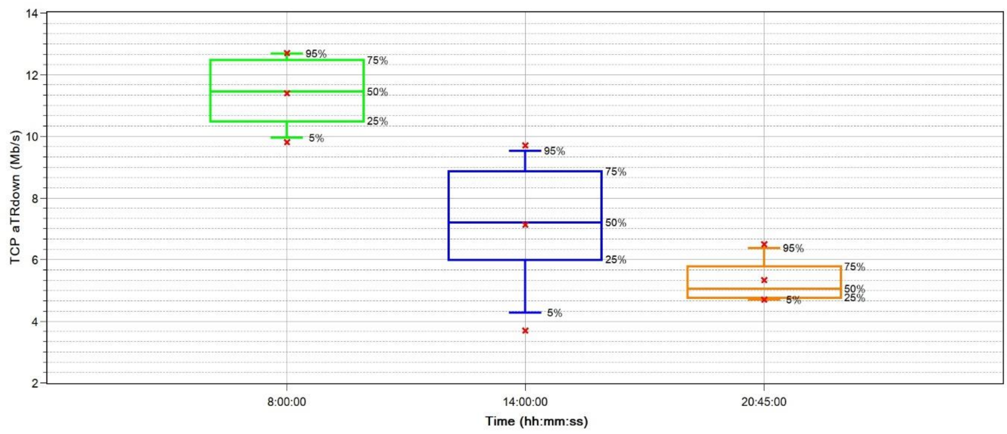

Fig. 4 TCP throughput TCP aTRdown mobile network at fixed access point

Impact of Qualitative Data Parameters on TCP throughput

Based on the mathematical model of behavior of the Internet access service and in the context of Regulation (EU) 2015/2120 we can determine that the resulting value of the measuring download or upload data process is the equivalent of data throughput on the end user's side TCP aTR $\equiv \nu$. The same as the system utilization of the distribution network, which is defined as $\Phi(\theta,\mu) = \frac{\theta}{\mu}$, we can define the system utilization of the user network as:

$$\Psi(\theta,\mu) = \frac{\theta}{\nu}, \tag{5}$$

which is so indirectly dependent on available data throughput ν . Due to the influence of the capacity of the distribution network and the influence of the results due to the buffers, respectively, an increase in frame delays or frames loss, respectively it is necessary to perform the measurement of the qualitative parameters according to the standard ITU-T Y.1564, which may indicate problems with insufficient distribution or access network capacity μ .

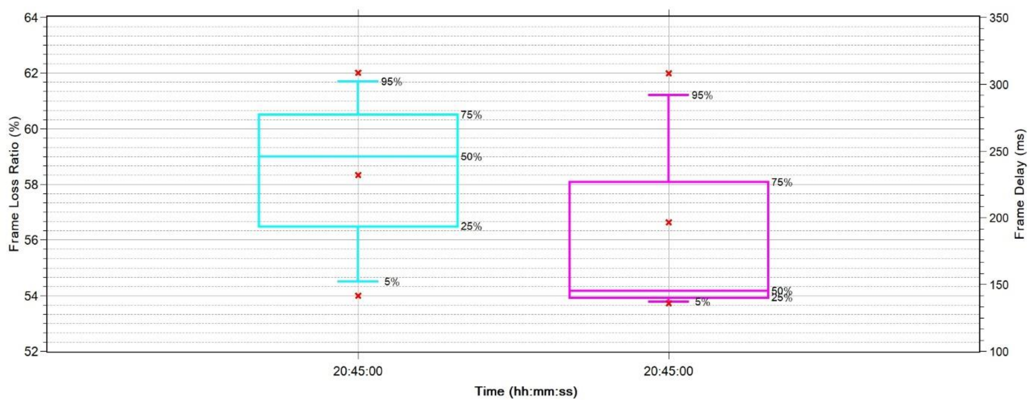

Fig. 5 Frame delay FD a Frame loss ratio FLR mobile services in fixed point (= 20:45:00).

Fig. 5 shows the result of measuring qualitative parameters of mobile data service at a fixed location (t_0 = 20:45:00). The specific monitored qualitative data parameters were Frame delay and Frame loss ratio. It turned out, that the throughput decrease was make by overloading of the distribution network. The result of the measurements shows that it is necessary for the operator to strengthen the capacity of the distribution network and the pitfalls of intelligent agriculture deployment.

RESULTS AND DISCUSSION

The article aims to analyse the impact of the distribution network's capacity on the intelligent agriculture service. Technology concepts and systems within the intelligent agriculture category are based on the use of information and communication technologies. The basic prerequisite for providing the intelligent agriculture service is to provide a stable internet access service. It turns out that the deployment of intelligent agriculture technologies needs to pay close attention to sufficient capacity of the distribution network. The general mathematical model of the distribution network behaviour as well as the measurement results show that, in touch with the Regulation (EU) 2015/2120, it is not enough to check for deviations or unavailability of the service, but also to measure qualitative data parameters that may indicate insufficient distribution network capacity. For example, in benchmarking with the technical specification of MEF 23.1, Performance Tier 2 (Regional), CoS Low.

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Determination of Mineral Nitrogen Losses under the Action of Water Erosion Processes in Maize Growing on Sloping Terrains

Gergana Kuncheva, Petar Dimitrov, Hristo Beloev

Abstract: *One of the main reasons for the reduction of soil productivity is water erosion, and its effect is depletion of soil layer, soil moisture holding capacity, soil organic matter, and nutrient supply. The availability of mineral nitrogen is a limiting factor for the productivity of ecosystems and unlike agricultural, in natural ecosystems, nitrogen cycles run with minimal losses. The efficiency of the use of mineral fertilizers is usually low and often much higher than plants actually need, that's why much of the mineral nutrients inserted by fertilizing are lost. The need for the development of sustainable farming systems requires soil protection from the impact of degradation processes and conservation of soil functions. For this purpose, different erosion control methods, measures and technologies are created and applied. In the present study the influence of conventional and soil protection technologies in the cultivation of maize on sloping terrains on the losses of mineral nitrogen under the influence of water erosion processes, is examined.*

Keywords*: maize, water erosion, mineral nitrogen loss, conventional technology, minimum tillage*

INTRODUCTION

The earth's surface is dominated by sloping terrains, which contributes to the occurrence of soil water erosion. Every year, as a result of its action, more than 75 Gt of the top soil layer is removed (Berhe et al., 2007). The related biogeochemical cycles of carbon (C) and nitrogen (N) are strongly affected by soil erosion as it affects their flow, storage, distribution, and residence time in the soil.

There are different ways of loss of nutrients from the soil. One is by surface removal under the action of water erosion processes, where they are taken away through surface water runoff and eroded soil to lower areas and in nearby water basins (Lal, 1991). Another way is by leaching from rain and irrigation. In dry areas in the United States, due to inefficient use or excessive application of fertilizers, after harvesting up to 90 kg ha-1 NO_3-N are leached at a depth between 1.5 and 2.5 m, below the root zone (Fuentes et al., 2003). Loss of nutrients can also occur through gaseous losses in the air, for example in alkaline soils or when organic fertilizers are applied on the soil surface, in the form of NO and NO_2, N_2 and ammonia. In a study of the impact of N-fertilizers applied on limestone sandy clay soils in the North China Plain (Cai et al., 2002), losses of nitrogen in the form of ammonia were found to be 30-39% of applied nitrogen in rice, 11-48% in maize, and about 20% in wheat (Mai Van Trinh, 2007).

Loss of nutrients leads to a number of environmental impacts. Nitrates, phosphates and other nutrients can cause eutrophication of water basins and contamination of drinking water, which creates conditions for potential health risks.

As a result of a study of the different erosion parameters of natural factors in the Republic of Bulgaria it is estimated that 62% of the territory of our country has a potential erosion risk of 10 t/ha y and for 43% of the territory the potential risk exceeds 10 t/ha y.

The consequences of the action of water erosion are of great importance for the economic life of humans, and the damage caused of it is enormous, which requires the application of a system of erosion control measures by implementation of different methods and technologies.

The purpose of this study is to examine mineral nitrogen losses in maize for grain cultivation, using conventional technologies, as well as application of soil protection, on sloping agricultural lands, on soil calcareous chernozem.

MATERIAL AND METHODS

The study was conducted in the period 2015-2017y., in the experimental field of the "Nikola Pushkarov" Institute of Soil Science, Agrotechnologies and Plant Protection - Sofia,

on the territory of the village of Trastenik, Rousse district, in non-irrigated conditions, on a medium eroded calcareous chernozem, on slope 5^o (8.7%).

A single factor field experiment with grain maize was conducted, using the block method, in four variants, in four replicates. The tested variants are:

13th - maize plots, grown by conventional technology, applied along the slope - control;

14 th - maize plots, grown by using conventional technology applied across the slope;

15 th - maize plots, grown by erosion control technology, including surface mulching with manure, all operations applied across the slope;

16 th - maize plots, grown by erosion control technology, including soil tillage without reversing the layer - loosening and soil protection operation vertical mulching with manure, slits with ducts forming, along with sowing and digging and furrowing along the hilling (advanced technology for minimum unconventional soil tillage) applied across the slope.

During the three year survey period, all the technological operations carried out in variant 13 and 14 were conventional and the same, the difference between them is only in the direction of their realization. In the control variant, they are applied along the slope, and in variant 14 in the transverse direction. In the same direction, the operations in variant 15 were carried out, before sowing, the erosion control method surface mulching with manure was applied (4500-5000 kg / ha), using a fertilizer trailer 1PTU-6.

In the last 16th variant, the erosion control methods are included, such as basic soil loosening as basic soil tillage, vertical mulching with manure, forming slits with ducts, along with sowing and digging and furrowing along the hilling operation. In this case, the chisel cultivator CP-9, a specialized machine for vertical mulching, the hoeing devices mounted on the SPS-6 pneumatic sowing frame and the KOV-4.2 cultivator, and a combined (forming slits and ducts) cultivator KRN 4.2.

The area of the grain maize experiment was after wheat predecessor and was fertilized with N10P8K8 kg/da, with phosphorus (potassium phosphate) and potassium (potassium chloride) fertilizers being introduced before plowing, and all nitrogen fertilizer (ammonium nitrate) applied pre-sowing.

The erosion measurements are carried out by the stationary method and for each variant there were constructed 15m x 5m sites with an area of 75 m^2 and containers for collecting runoff. Besides the measurement of the erosion indicators (volume of surface water runoff and quantity of eroded soil), the concentration of available forms of nitrogen - ammonium and nitrate in the eroded soil and nitrate in the water runoff was measured by the Keldahl method.

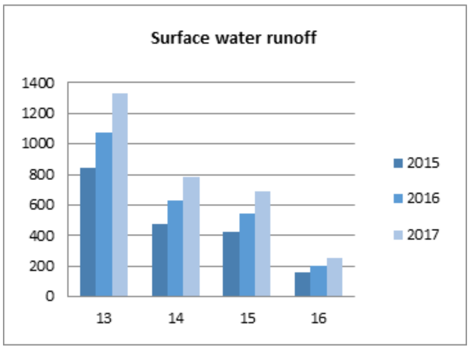
RESULTS AND DISCUSSION

The results of the erosion studies, performed for the three years period of the experiment are presented in table 1 and fig. 1. It can be seen that the values of surface water runoff and eroded soil are the lowest in variant 16, where sowing maize was cultivated applying advanced soil protection technology for minimum and unconventional soil tillage. Using this technology, surface water runoff is reduced from 5.1 to 5.5 times, and eroded soil from 22.2 to 23.1 times, compared to a control, grown along the slope. It should be noted that this effect persists throughout the study period. Lower erosion control indicators are observed in variant 15 with application of soil protection technology with surface mulching with manure. The decrease of the volume of surface water runoff is 1.9 to 2.2 times, and the amount of the eroded soil is 2.7 to 3.1 times, compared to the control variant 13.

Table 1 *Total volume of surface water runoff and amount of eroded soil 2015-2017y.*

Date	Volume of erosive rainfall l/m²	Surface water runoff m³/ha				Eroded soil kg/ha			
		Variant				Variant			
		13	14	15	16	13	14	15	16
26.05.15	16.0	266.426	154.983	142.614	51.378	3758.7	1501.6	1375.1	167.0
10.06.15	18.0	226.137	124.068	112.705	42.581	2879.9	1094.9	982.9	125.3
02.07.15	14.5	201.227	110.034	97.933	37.478	2517.8	939.5	843.6	109.3
21.08.15	51.0	154.224	83.797	74.407	28.856	1930.7	704.3	624.8	84.3
For 2015 y.	99.5	848.014	472.882	427.659	160.293	11087.1	4240.3	3826.4	485.9
05.05.16	20.0	265.263	159.468	140.964	52.023	3457.1	1375.7	1263.5	156.2
24.05.16	16.0	233.263	137.143	120.722	44.740	2920.0	1140.4	1050.0	129.7
06.06.16	12.0	174.737	98.073	84.217	32.601	2139.5	795.8	736.4	93.4
12.06.16	18.0	224.842	133.555	115.663	42.948	2802.0	1063.3	983.8	123.8
11.08.16	15.0	181.053	101.262	83.133	32.948	2192.2	812.8	727.1	95.4
For 2016 y.	81.0	1079.16	629.501	544.699	204.624	13510.8	5188.0	4760.8	598.5
06.05.17	20.2	255.582	149.591	133.060	50.269	3116.7	1240.6	1162.8	140.1
27.05.17	13.0	168.435	99.785	88.198	32.618	2017.7	748.2	697.6	89.0
19.06.17	11.0	170.149	95.054	85.230	31.812	2039.6	756.3	705.7	89.7
02.07.17	32.0	261.940	153.979	137.809	51.544	2960.6	1136.9	1059.6	133.4
13.08.17	18.0	220.299	129.462	114.912	41.477	2692.2	1036.7	925.9	119.2
03.09.17	42.0	256.567	153.979	134.841	50.336	2885.9	1118.3	1030.4	130.0
For 2017 y.	136.2	1332.97	781.850	694.050	258.056	15712.7	6037.0	5582.0	701.4

ANOVA Surface water runoff: HSD[0.05]=420.41; HSD[0.01]=574.7; *1 vs 2 P<0.05; 1 vs 3 P<0.05; 13 vs 16 P<0.01; 14 vs 15 NS; 14vs16 P<0.05; 15 vs 16 NS;* ***ANOVA Eroded soil: HSD[0.05]=3453.12; HSD[0.01]=4720.44;*** *13 vs 14 P<0.01; 13 vs 15 P<0.01; 13 vs 16 P<0.01; 14 vs15 NS; 14 vs 16 P<0.05; 15vs16 P<0.05*



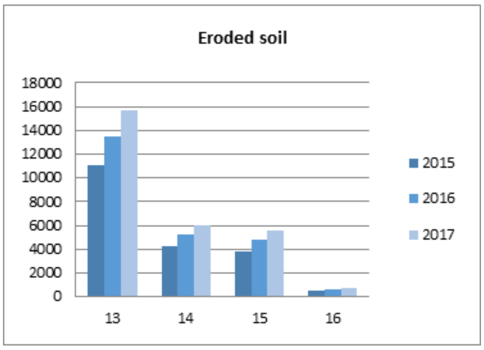


Fig. 1 Erosion control efficiency of the applied technologies for soil tillage, maize experiment, for the period 2015-2017 y.

Table 2 *Mineral nitrogen soil content ($N\text{-}NH_4$ (mg/kg), $N\text{-}NO_3$ (mg/kg)), by variants, 2015 – 2017y.*

Year	Before sowing				Maximum growth stage				After harvesting			
	Variant				Variant				Variant			
	13	14	15	16	13	14	15	16	13	14	15	16
2015 y.	61.58	68.81	71.00	97.14	27.32	27.80	48.30	66.18	23.03	23.08	39.68	49.36
2016y.	69.49	68.70	105.9	74.19	37.45	36.80	40.89	76.20	33.43	33.68	69.39	79.57
2017 y.	35.11	35.02	55.44	58.56	29.15	36.77	60.57	49.57	26.43	29.31	40.38	56.74

ANOVA; p=0.002182; HSD[.05]=23.04; HSD[.01]=28.66; *13 vs 14 nonsignificant; 13 vs 15 nonsignificant;13 vs 16 P<.01 14 vs 15 nonsignificant;14 vs 16 P<.01;15 vs 16 nonsignificant*

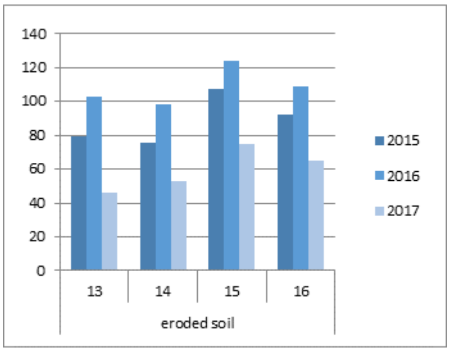
The agrochemical indicators of the soil at different phases of the development of the crop, for the three years of research are presented in Table 2. Before sowing, ammonia and nitrate nitrogen are the highest in variant with surface mulching with manure and in variant with minimum tillage and vertical mulching, due to the nitrogen intake with the mulching material, compared to conventional technologies applied along the slope and across the slope. This tendency remains in the other phases of the development of maize.

Along with that, the levels of nutrients in the surface water runoff and in the eroded soil are determined. The results obtained from the studies show that the mineral nitrogen forms in the 13th variant are the lowest, with conventional tillage, applied along the slope, which is most exposed to the action of water erosion and has the highest soil losses and volume of surface water runoff.

Table 3 *Avarage content of N-NH_4 (mg/kg), N-NO_3 (mg/kg), in the eroded soil, N-NO_3 (mg/l), in the surface water runoff, 2015-2017y.*

Year	Eroded soil				Surface water runoff			
	Variant				Variant			
	13	14	15	16	13	14	15	16
For 2015y.	79.74	75.81	107.43	92.40	11.29	11.21	12.20	8.88
For 2016y.	102.87	98.49	123.92	108.17	8.49	8.56	13.91	6.19
For 2017y.	46.29	52.58	75.20	64.75	12.03	12.49	14.78	11.61
Avarage 2015-2017y.	60.87	58.10	77.12	88.44	10.60	10.75	13.63	8.89

ANOVA; NS



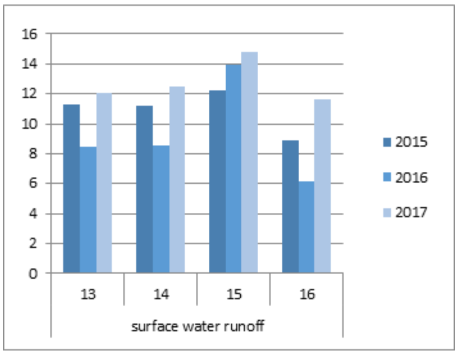


Fig. 2 Avarage content of N-NH_4 (mg/kg), N-NO_3 (mg/kg), in the eroded soil, N-NO_3 (mg/l), in the surface water runoff, 2015-2017y.

From the analysis of the experiments with maize for grain, it can be concluded that the application of manure in soil protection practices leads to an increase in the concentration of available forms of nitrogen in the eroded soil and in the surface water runoff as a result of the increased amount of these elements in the surface soil layer. The results of the analysis are presented in table. 3 and fig.1.

On the basis of the results for the volume of surface water runoff and the amount of eroded soil as well as the mineral nitrogen concentration in them, the losses of this chemical element, obtained during erosive rainfalls, during the studied period were calculated. The data on the losses occurring both with the surface water runoff and the exported soil are presented in table. 4 and fig.3. For maize growing on sloping terrain, using conventional technology, mineral nitrogen losses are 12.46 kg/ha active substance, average over the three-year study period. Using conventional technology across the slope, the loss of mineral nitrogen from water erosion is 7.08 kg/ha active substance. The mineral nitrogen loss on average for the three-year period of the experiments with the surface application of manure is 8.32 kg/ha. The lowest nitrogen losses are in the variant with application of the advanced technology for minimum and unconventional soil tillage, with the average annual loss for the studied period of 1.96 kg/ha.

Table 4 *Losses of available of nitrogen N (N-NO_3^- + N- NH_4^+) with eroded soil and surface water runoff (kg/ha),at erosive rainfalls 2015-2017 y.*

Date	Rainfall l/m²	Eroded soil, (N-NO_3^- + N- NH_4^+), kg/ha				Surface water runoff N-NO_3^-, kg/ha				Total losses of mineral nitrogen, kg/ha			
		Variant				Variant				Variant			
		13	14	15	16	13	14	15	16	13	14	15	16
26.05.15	16.0	0.347	0.124	0.142	0.014	2.632	1.398	1.462	0.388	2.979	1.513	1.476	0.402
10.06.15	18.0	0.462	0.168	0.192	0.027	3.177	1.740	1.952	0.553	3.639	1.908	2.144	0.58
02.07.15	14.5	0.111	0.039	0.056	0.006	2.487	1.430	1.828	0.323	2.598	1.469	1.884	0.329
21.08.15	51.0	0.104	0.038	0.070	0.007	1.369	0.735	0.933	0.182	1.473	0.773	1.003	0.189
Total for 2015y.	99.5	1.025	0.368	0.459	0.053	9.666	5.673	6.634	1.500	10.691	6.041	7.093	1.553
05.05.16	20.0	0.482	0.163	0.198	0.020	2.090	1.275	1.735	0.363	2.579	1.438	1.933	0.383
24.05.16	16.0	0.276	0.112	0.129	0.014	2.076	1.235	1.692	0.353	2.352	1.347	1.821	0.367
06.06.16	12.0	0.194	0.076	0.098	0.010	1.363	0.770	1.503	0.149	1.557	0.846	1.601	0.159
12.06.16	18.0	0.339	0.112	0.115	0.012	2.012	1.197	1.594	0.268	2.351	1.309	1.709	0.28
11.08.16	15.0	0.172	0.061	0.065	0.009	1.611	0.910	0.963	0.174	1.783	0.971	1.028	0.183
Total for 2016y.	81.0	1.464	0.525	0.606	0.066	9.15	5.38	7.49	1.31	10.614	5.905	8.096	1.376
06.05.17	20.2	0.193	0.085	0.095	0.009	3.348	2.097	2.230	0.796	3.541	2.182	2.325	0.805
27.05.17	13.0	0.106	0.040	0.059	0.007	2.419	1.455	1.647	0.281	2.525	1.495	1.706	0.288
19.06.17	11.0	0.117	0.024	0.047	0.005	2.687	1.522	1.554	0.464	2.804	1.546	1.601	0.469
02.07.17	32.0	0.098	0.059	0.073	0.007	2.292	1.318	1.506	0.479	2.39	1.377	1.579	0.486
13.08.17	18.0	0.119	0.051	0.074	0.008	3.481	2.061	2.095	0.646	3.6	2.112	2.169	0.654
03.09.17	42.0	0.083	0.044	0.070	0.009	1.121	0.898	0.786	0.289	1.204	2.942	0.856	0.298
Total for 2017y.	136.2	0.716	0.304	0.419	0.045	15.347	9.352	9.818	2.955	16.063	9.656	10.237	3.00
Avarage for three years		1.06	0.40	0.49	0.05	11.38	6.68	7.83	1.90	12.46	7.08	8.32	1.96

ANOVA; P<.0001, HSD[.05]=0.51; HSD[.01]=0.63, *13 vs 14 P<.01;13 vs 15 P<.01;13 vs 16 P<.01;14 vs 15 nonsignificant;13 vs 16 P<.01;15 vs 16 P<.01*

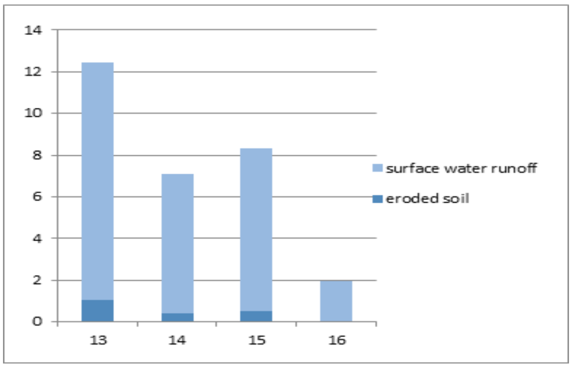


Fig. 1 Losses of available of nitrogen N (N-NO_3^- + N- NH_4^+) with eroded soil and surface water runoff (kg/ha),at erosive rainfalls 2012-2015 y.

As can be seen from the presented tables, the losses of mineral nitrogen from water erosion occur mainly with the surface water runoff in the different variants for growing of the studied agricultural crop. The major part of the nitrogen is exported in the form of nitrate ions. In the sloping arable lands with application of conventional technology, 91.33% of nitrogen losses occur with surface water runoff and 8.67% - with eroded soil. In variant 14, nitrogen losses with surface water runoff are 94.35% of total mineral nitrogen losses. In variant 15, with the water flow, 94.11% of the losses of mineral nitrogen occur, and in case of variant 16 - 96.94%.

CONCLUSION

1. The lowest values of the erosion indicators, the amount of eroded soil and the surface water runoff in the experiments carried out as well as the highest losses of mineral nitrogen are observed with the application of the advanced technology for minimum and unconventional soil tillage with vertical mulching with manure, when growing corn on

inclined terrains. In its implementation, the surface water flow is reduced from 5.1 to 5.5 times, and the eroded soil decreases from 22.2 to 23.1 times, compared to the control grown conventionally along the slope.

2. Almost all mineral nitrogen losses occur with surface water runoff (between 91-97%) and a little part with eroded soil. With the application of soil protection technologies (variants 15 and 16), mineral nitrogen losses are in higher degree occur with the water flow (94-97%), compared to those, using conventional (91-94%).

3. The lowest nitrogen losses occur in variant 16 with unconventional soil tillage technologies with 10.50 kg/ha lower than the control grown by conventional technology, applied along the slope. In variant 15, despite the reduction of surface water runoff and the amount of eroded soil, the concentrations of available nitrogen forms in them are high, therefore the reported losses are only 4.13 kg/ha lower than those of variant 13, although the erosion control effect is significantly higher. This is due to the surface application of manure.

4. Soil-protection technology for minimum and unconventional soil tillage using manure as a mulching material for growing maize on sloping terrains, has a significant erosion control effect, reduces surface water runoff and soil loss, increases water retention and increases the efficiency of used mineral and organic fertilizers. This leads to an improved feeding and development of the cultivated agricultural crop and thus to higher productivity.

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Losses of Mineral Nitrogen under the Influence of Water Erosion Processes in the Wheat Cultivation on Sloping Agricultural Lands

Gergana Kuncheva, Hristo Beloev, Petar Dimitrov

Abstract: *Soil water erosion is a degradation process with a significant negative impact on the soils in the world and in Bulgaria. One of these consequences is the loss of nutrients, removed with surface water runoff and eroded soil. For the development of sustainable agriculture, preservation of soil fertility and protection of the environment from pollution, it is necessary to improve the efficiency of the use of mineral fertilizers as well as to limit water erosion processes. For this purpose, it is necessary to apply erosion control technologies for growing agricultural crops on slope arable lands. In the present study the influence of conventional and soil protection technologies in the cultivation of wheat on sloping arabale lands on the losses of mineral nitrogen under the influence of water erosion processes, is examined.*

Keywords*: loss of mineral nitrogen, water erosion, conventional technologies, soil protection technology, wheat, minimum tillage, vertical mulching.*

INTRODUCTION

Much of the soil nutrients loss is due to the action of water erosion, which directly leads to a decrease in the productivity of ecosystems. According to the studies, as a result of the action of the water erosion processes, there is a decline in the yields of the crops, between 0.1 and 0.4%. If the average annual yield reduction is 0.3% and it will be the same for the period from 2015y. to 2050y. and there are 1.53 billion hectares of arable land in the world, the loss of yields due to erosion would be equivalent to removal from harvesting of 4,5 million hectares of agricultural land annually or 150 million hectares for the period up to 2050y. (Foley et al., 2011).

In most natural ecosystems, the availability of nitrogen is a limiting factor for the productivity of ecosystems and nitrogen cycles run with minimal losses. Through the cultivation of nitrogen-fixing crops and the application of inorganic nitrogen fertilizers, people bring twice as much available nitrogen into the soil as compared to natural processes, thus significantly increase the production of biomass. However, since the efficiency of the use of mineral fertilizers is usually low and often much higher amounts (FAO, 2015) are applied than plants actually need, much of the mineral nutrients imported by fertilizing are lost. This leads to many related negative effects on the environment and human health, such as increased N_2O emissions, nitrogen fertilizer pollution, surface and ground water contamination, and food products (Galloway et al., 2008).

FAO analyzes show that global increases in nitrogen inputs in agricultural systems cannot lead to higher productivity without causing significant environmental damage (FAO, Rome, 2015).

Nutrient elements such as nitrogen, phosphorus, potassium, calcium, etc. are exported from the areas subjected to water erosion, with surface water runoff and with eroded soil (D. Piementel, N. Kounang, 1998). The study of Li Wang et al (2010) found that on the slope of 15^0, soil organic matter, available forms of nitrogen, phosphorus and potassium at the top of the slope were 74.64%, 37.92%, 55%, 86% and 51.95% in comparison with their content to its base.

In the world, 31% of land is subject to action of water erosion or it is about 1.1 billion hectares (Dobrovolsky, 2008). Annually, under its influence of water erosion, according to the Reich (2001), there are removed 130 billion tonnes of soil. Nowadays, around 430 million hectares of land have been destroyed and lost in various countries in the world by this degradation process (Dimitrov, 2016). Worldwide, soil water erosion reaches the largest dimensions in Asia, Africa and America. The annual loss of soil in India from erosion

processes is 16 t/ha. Water erosion actively affects 140 mha of land, resulting in the loss of 6,000 Mt of fertile soil containing 5,5 Mt NPK(Meena N. K., 2017). Troeh (1980) estimates that in the United States the annual nutrient loss from soil in the process of water erosion, equals 20 billion $.

The many negative consequences of the action of water erosion processes require the application of erosion control measures, methods and technologies in order to preserve the soil fertility and to improve the feeding of the cultivated plants by improving the efficiency of the applied fertilizers and obtaining stable yields.

The purpose of the present study is to determine the loss of mineral nitrogen with surface water runoff and eroded soil in wheat growing by conventional and soil protection technologies, on soil calcareous chernozem, on slope of 5 ° (8.7%).

MATERIAL AND METHODS

The survey was conducted in the period 2015-2017 y. in the experimental field of Institute of soil science, agricultural technologies and plant protection "Nikola Pushkarov” - Sofia, in the village of Trastenik, Ruse, without irrigation, on medium eroded calcareous chernozem on slopping agricultural lands with inclination 5º (8.7%). Field trials with wheat were made by the block method, in four variants, in four replicates.

The variants of the experiments are:

5 th - wheat plots, grown by conventional technology, applied along the slope - control;

6 th - wheat plots, grown by conventional technology, applied across the slope;

7 th - wheat plots, grown by soil protection technology including the erosion control measure - surface mulching with manure, applied across the slope

8 th - wheat plots, grown under the advanced soil protection technology including erosion control measures vertical mulching with manure and direct sowing, as well as some plant protection operations to control weeds, pests and plant diseases, all operations applied across the slope.

During the research period, every year, all the technological operations carried out in variant 5 and 6 are conventional were the same, the difference between them was only in the direction of their application. In the control, they are carried out along the slope and in variant 6 in the transverse direction. In the same direction have been carried out and operations in the variant 7, as in it before sowing was carried out erosion control method surface mulching with manure (4500-5000 kg/ha), performed across the slope with fertilizer spread trailer 1 PTU – 6.

In the last 8th variant before sowing, across the slope is carried out vertically (into the soil) mulching with manure, in band scheme (distance between the slots 1,4 m and a space between the bands in the field 3 m) of a depth of 0,40 m with the that was vertically mulched with compost (3500-4000 kg/ha) with the reconstructed machine breaker-dead furrower ЩН 2-140, which consists a frame, cuttings and molehills making working bodies, as well as bunker for plant residues

The areas used for experiments were with predecessor for wheat - grain corn. In the area of the experiment, fertilization was carried out mainly with $N_{15}P_{10}K_8$ kg/da, with the total amount of the phosphorus (superphosphate) and potassium (potassium chloride) fertilizers being incorporated before sowing and the nitrogen fertilizer (ammonium nitrate) divided into two dosages, one third of it was applied before the sowing, and the other 2/3 - in the spring.

The erosion measurements are carried out by the stationary method and for each variant there were constructed 15m x 5m sites with an area of 75 m^2 and containers for collecting runoff. Besides the measurement of the erosion indicators (volume of surface water runoff and quantity of eroded soil), the concentration of available forms of nitrogen - ammonium and nitrate in the eroded soil and nitrate in the water runoff was measured by the Keldahl method.

RESULTS AND DISCUSSION

The applied advanced soil protection technology for minimum and unconventional soil tillage for growing wheat on sloping arable lands have a significant erosion control effect due to increased soil infiltration capacity and improved soil protection effectiveness of vegetation and plant debris. This technology reflects not only the volume of surface water runoff and the amount of eroded soil, but also the loss of nutrients by water erosion.

The results obtained from the erosion studies, by years, are presented in table 1 and fig 1. It can be seen that in the variant with minimum tillage and vertical mulching with manure, the volume of surface water runoff decreases from 2.6 to 2.9 times and the eroded soil from 6.3 to 6.5 times, compared to control, variant 5, grown along the slope and this effect being maintained throughout the study period. A less erosion control effect was observed in variant 7 with application of soil protection technology using surface mulching with manure. The reduction of the surface runoff is from 1.6 to 1.8 times, and in the quantity of eroded soil it is 3.1 to 3.4 times, compared to the control. The lowest is the erosion control efficiency of the variant with conventional tillage across the slope. Here the decrease is from 1.3 to 1.5 times for the volum of water runoff, and the soil loss from 1.7 to 1.9 times, compared to the control.

Table 1 *Total volume of surface water runoff and amount of eroded soil 2015-2017y.*

Date	Rain l/m^2	Surface water runoff m^3/ha				Eroded soil kg/ha			
		Variant				Variant			
		5	6	7	8	5	6	7	8
26.05.15	16.0	165.985	128.000	103.794	64.483	1983.2	1181.9	640.8	315.0
10.06.15	18.0	140.584	93.895	80.643	50.344	1663.9	884.0	510.9	258.3
02.07.15	14.5	118.467	78.947	66.945	41.552	1397.9	763.9	432.7	215.7
For 2015 y.	48.5	425.036	300.842	251.384	156.379	5045.0	2829.8	1584.4	789.0
05.05.16	20.0	170.382	122.628	101.661	63.761	1925.1	1079.5	605.9	301.4
24.05.16	16.0	148.397	98.978	89.302	52.657	1598.2	926.0	491.3	247.5
06.06.16	12.0	109.924	73.577	62.193	37.687	1211.9	651.9	355.0	185.7
12.06.16	18.0	142.443	100.292	83.721	50.866	1567.1	888.2	471.7	243.6
For 2016 y.	66.0	571.146	395.475	336.877	204.971	6302.3	3545.6	1923.9	978.2
29.04.17	16.0	152.528	103.830	90.863	56.556	1578.8	878.9	495.2	246.3
06.05.17	20.2	165.626	123.319	99.604	62.284	1900.2	1062.3	598.9	300.4
27.05.17	13.0	105.934	71.915	59.808	36.979	1128.2	604.1	341.0	173.4
19.06.17	11.0	106.374	71.489	59.425	36.616	1136.1	602.9	337.3	175.2
02.07.17	32.0	169.231	128.511	103.898	65.619	2035.6	1206.2	654.2	324.3
For 2017 y.	92.2	699.693	499.064	413.398	258.54	7778.9	4354.4	2426.6	1219.6

***ANOVA; Surface water runoff**: p<.0001;HSD[.05]=21.62; HSD[.01]=26.67; 5 vs 6 P<.01;5 vs 7 P<.01; 5 vs 8 P<.01; 6 vs 7 nonsignificant; 6 vs 8 P<.01; 7 vs 8 P<.01; **Eroded soil** p<.0001; HSD[.05]=223.02; HSD[.01]=275.14; 5 vs 6 P<.01; 5vs7 P<.01; 5 vs 8 P<.01; 6 vs 7 P<.01; 6 vs 8 P<.01; 7 vs 8 P<.05*

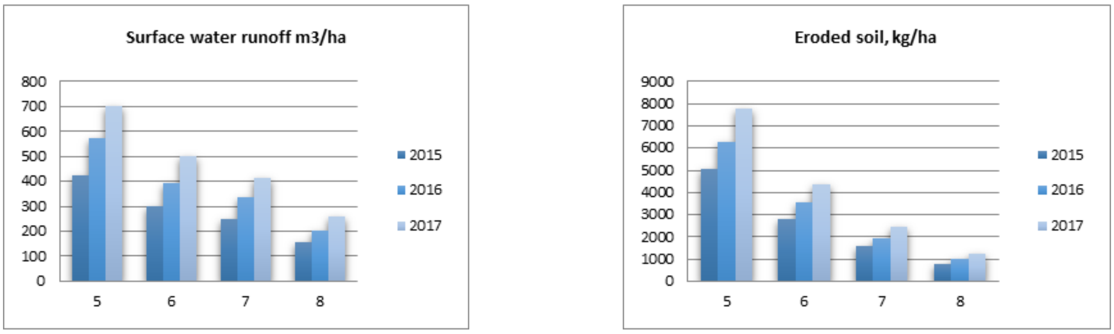


Fig. 1 Volume of surface water runoff (m^3/ha) and amount of eroded soil (kg/ha) 2015-2017 y.

Table 2 *Mineral nitrogen soil content (N-NH_4 (mg/kg), N-NO3 (mg/kg)), by variants, 2015 – 2017y.*

Year	Before sowing				Maximum growt stage				After harvesting			
	Variant				Variant				Variant			
	5	6	7	8	5	6	7	8	5	6	7	8
2015 y.	59.56	58.23	68.44	85.42	63.29	66.30	85.87	106.74	15.35	16.55	17.84	29.34
2016y.	35.00	37.09	69.18	67.94	29.67	30.70	51.27	71.06	19.20	19.80	25.52	28.71
2017 y.	32.25	32.87	51.27	69.30	37.88	36.08	53.98	89.07	31.29	27.54	45.93	53.25

ANOVA: 1 vs 4, p=0.008479

The mineral nitrogen content (N-NH_4 (mg/kg), N-NO_3 (mg/kg)) of the soil at different stages of the development of the crop, for the three years of research are presented in table 2. The highest levels of soluble mineral forms of nitrogen are observed in the variants with minimum soil tillage with vertical mulching with manure and in the variant with surface mulching with manure. As can be seen from the data, the input of a material with high nitrogen content significantly influences the agrochemical content of soil in variant 7 and variant 8.

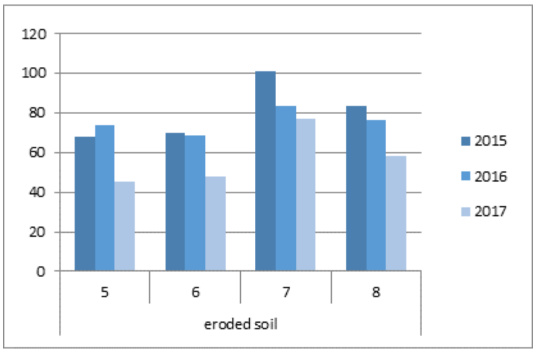
From samples taken from the collected runoffs, by variants, the concentrations of the mineral nitrogen forms in the surface water flow and in the eroded soil were measured. Average concentrations by years are shown in Table 3.

There is higher concentration of mineral nitrogen forms in variants with organic fertilizer applications (variants 7 and 8). This is most strongly observed in the variant with application of surface mulching. The concentration of mineral nitrogen in the eroded soil as well as in the surface water runoff, are affected by the stock at the moment of the erosive rainfalls as well as by the applied manure and the way of its deposition.

Table 3 *Average content of N-NH_4 (mg/kg), N-NO_3 (mg/kg), in the eroded soil, N-NO3 (mg/l), in the surface water runoff, 2015-2017y.*

Year	Eroded soil				Surface water runoff			
	Variant				Variant			
	5	6	7	8	5	6	7	8
For 2015y.	68.11	69.92	101.24	83.92	11.65	13.25	22.67	12.58
For 2016y.	73.63	68.93	83.31	76.57	10.84	11.07	16.56	11.56
For 2017y.	45.02	47.88	77.31	58.06	9.93	10.49	15.76	10.04
Avarage 2015-2017y.	62.25	62.24	87.29	72.85	10.81	11.60	18.33	11.39

***ANOVA: Eroded soil p**= 1.00;* **Surface water runoff *p**= 1.00*



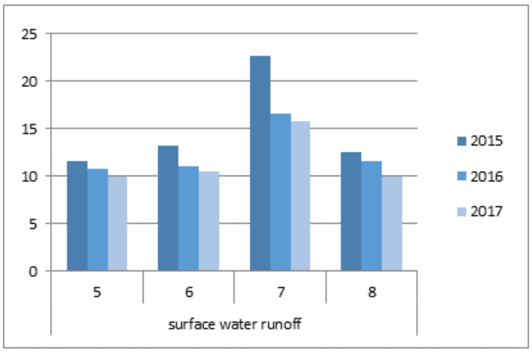


Fig. 2 Average content of N-NH_4 (mg/kg), N-NO_3 (mg/kg), in the eroded soil, N-NO_3 (mg/l), in the surface water runoff, 2015-2017y.

Based on the data for amount of eroded soil, volume of surface water runoff and the concentration of mineral nitrogen forms, nitrogen losses by erosive rainfalls, occurring during the vegetation of the crop, were calculated. Losses of ammonium and nitrate nitrogen with

surface water runoff and eroded soil were lower in variant 8 compared to conventional technology, applied along the slope - control, with 2,66 times average over the three-years study period. In variant 7, despite the reduction of surface water runoff and the amount of eroded soil, the concentrations of available nitrogen forms in them are high, so the reported losses are similar to variant 5, despite the proven erosion control effect. This is due to the surface application of manure.

Table 4 *Losses of available of nitrogen N ($N\text{-}NO_3^-$ + $N\text{-} NH_4^+$) with eroded soil and surface water runoff (kg/ha),at erosive rainfalls 2015-2017 y.*

Date	Rainfall l/m^2	Eroded soil, ($N\text{-}NO_3^-$ + $N\text{-} NH_4^+$), kg/ha				Surface water runoff $N\text{-}NO_3^-$, kg/ha				Total losses of mineral nitrogen, kg/ha			
		Variant				Variant				Variant			
		5	6	7	8	5	6	7	8	5	6	7	8
26.05.15	16.0	0.129	0.085	0.076	0.029	1.934	1.696	2.594	0.773	2.062	1.780	2.67	0.802
10.06.15	18.0	0.104	0.052	0.045	0.019	1.683	1.224	1.612	0.679	1.742	1.296	1.657	0.698
02.07.15	14.5	0.107	0.060	0.042	0.019	1.380	1.046	1.540	0.508	1.487	1.104	1.582	0.526
Total for 2015y.		0.340	0.197	0.163	0.067	4.997	3.966	5.698	1.967	5.291	4.18	5.861	2.033
05.05.16	20.0	0.146	0.079	0.048	0.024	2.711	1.962	2.134	1.112	2.857	2.041	2.183	1.136
24.05.16	16.0	0.125	0.053	0.036	0.014	1.730	1.194	1.615	0.620	1.858	1.247	1.651	0.634
06.06.16	12.0	0.067	0.042	0.028	0.013	0.856	0.592	0.755	0.297	0.923	0.634	0.783	0.310
12.06.16	18.0	0.134	0.071	0.048	0.025	1.139	0.819	1.256	0.464	1.273	0.890	1.304	0.489
Total for 2016y.		0.464	0.245	0.160	0.075	6.191	4.377	5.578	2.370	6.655	4.621	5.739	2.445
29.04.17	16.0	0.066	0.038	0.051	0.021	1.98	1.375	2.87	0.857	2.046	1.413	2.921	0.878
06.05.17	20.2	0.083	0.061	0.041	0.016	0.848	0.644	0.569	0.286	0.931	0.705	0.610	0.302
27.05.17	13.0	0.067	0.036	0.021	0.008	0.760	0.519	0.445	0.234	0.827	0.555	0.466	0.242
19.06.17	11.0	0.045	0.022	0.020	0.008	1.196	0.818	0.713	0.338	1.241	0.840	0.733	0.346
02.07.17	32.0	0.083	0.053	0.063	0.019	2.216	1.964	2.290	0.976	2.300	2.017	2.353	0.995
Total for 2017y.		0.344	0.21	0.196	0.072	6.95	5.233	6.517	2.596	7.300	5.44	6.704	2.668
Avarage for three years		0.385	0.217	0.170	0.07	6.031	4.532	5.931	2.311	6.415	4.749	6.101	2.382

ANOVA *P=0.003584;HSD[.05]=2.63; HSD[.01]=3.6, 5 vs 6 nonsignificant, 5 vs 7 nonsignificant, 5 vs 8 P<.01, 6 vs 7 nonsignificant, 6 vs 8 P<.05, 7 vs 8 P<.01*

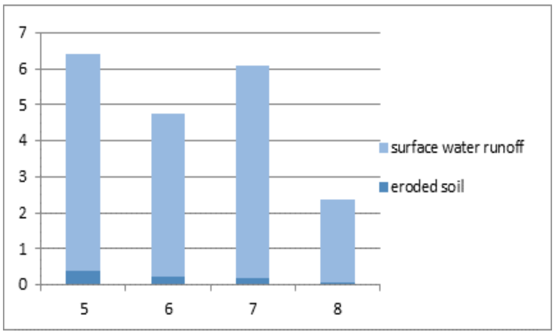


Fig. 3 Losses of available of nitrogen N ($N\text{-}NO_3^-$ + $N\text{-} NH_4^+$) with eroded soil and surface water runoff (kg/ha), at erosive rainfalls 2015-2017 y.

As can be seen from the tables (tables 3 and 4), the losses of mineral nitrogen from water erosion occur mainly with the surface water runoff in the different variants of the experiment. The major part of the nitrogen is loss in the form of nitrate ions. In the control variant, wheat grown along slope with application of conventional technology, 93.77% of nitrogen losses occur with surface water runoff and 6.23% with eroded soil. In variant 6, surface water runoff losses are 95.43% of total mineral nitrogen losses. In variant 7, with the water flow, 97.21% of the losses of mineral nitrogen occur, and in case of variant 8 - 97.0% . In Fig. 3 are shown loss of available forms of N ($N\text{-}NO_3^-$ + $N\text{-} NH_4^+$) with eroded soil and surface water runoff (kg / ha), on average for the three years of study (2015-2017y.).

The loss of mineral nitrogen in the growing wheat on carbonate chernozem on sloping terrains by conventional technology (variant 5) resulted in a mineral nitrogen loss of 6,42 kg/ha of active substance, averaged over the three years period of study. This as well as the lower water retention capacity, the higher compaction resulting from the erosion processes, influences the development of the cultivated crop. In the variant with conventional tillage, applied across the slope (variant 6), the average annual nitrogen loss is 4.75 kg/ha. In the variant with surface mulching with manure, the nitrate nitrogen concentration in the surface water runoff is the highest and overall losses are high, irrespective of the erosion control effect and improved agrochemical content of the soil. The lowest is the loss of mineral nitrogen using advanced technology for minimum and unconventional tillage for growing wheat on slope arable lands (variant 8). With this variant, the losses are 2.38 kg/ha. In the variant with surface mulching, mineral nitrogen losses are similar to control losses due to the surface application of the manure. However, in this variant, the erosion control effect has been proven and the agrochemical indicators of the soil are improved.

CONCLUSIONS

1. The highest amount of eroded soil and volume surface water runoff, as well as the highest mineral nitrogen losses, are observed in sowings with applying conventional technologies for growing wheat on slope arable lands, along the slope. Using the advanced technology for minimum and unconventional soil tillage, surface water runoff decreases 1.6 to 1.8 times and the amount of eroded soil decreases from 6.3 to 6.5, compared to the control variant.

2. Almost all mineral nitrogen losses (94-97%) occur with surface water runoff and only 3-6 % are loss with eroded soil and are in nitrate form. In variants 7 and 8, and this percentage is higher in variants 7 and 8, with application of soil protection technologies, than in conventionally grown.

3. Mineral nitrogen losses when growing wheat on sloping terrains with the application of advanced technology for minimum and unconventional soil tillage using manure, such as mulch, are reduced with 4.04 kg/ha active substance.

4. In application of technology with surface mulching with manure, nitrogen losses are almost the same as in the control variant due to the surface application of this organic material, although the erosion indicators in the implementation of this soil protection technology are significantly reduced.

5. The applied erosion control technologies reduce surface water runoff and thus improve water retention as well as the efficiency of applied mineral nitrogen and organic fertilizers. This leads to higher soil productivity and improved crop feeding and development on sloping terrains, with calcareous chernozem.

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Using the EFQM Model in Selected Organization

Miroslav Pristavka, Pavol Findura, Plamen Kangalov, Ursula Malaga-Tobola, Maciej Kubon

Abstract: *The task of the thesis is the analysis and subsequent application of statistical methods in quality management and improvement of the quality system. The paper determines appropriate methodology and discusses quality issues by managing quality, characteristics, history, description and self-assessment of the EFQM excellence model. The goal of the paper is to process and evaluate the state of the state according to the EFQM model in the organization (SMZ, a.s. Jelšava). Suggested solutions should increase the perception of workers that they are part of an exceptional organization.*

Keywords: *self-assessment, review, improvement, results.*

INTRODUCTION

The main purpose of this work is to evaluate the performance of a specific organization using the EFQM method. The paper deals with the analysis of the complex presentation of the EFQM Model of Excellence[1,6]. It is necessary to present a graphical representation of this model where it is possible to monitor the interconnection of the individual criteria of this model. It is necessary to introduce and define each criterion in terms of leadership, people, strategy, partnership, resources and processes. And as well as each of the criteria found in the results area, where results - people, results - customers, results - the company and the key results of their design and usage [7,8].

In the selected organization, EFQM model data applied to the selected method is described in the theoretical part. The application of the EFQM Excellence Model is followed in order to capture non-financial performance indicators in the organization [2,5,6].

Improving the quality of management processes and introducing modern quality systems is one of the ways to stay in the labor market in today's competitive times. The Model of Excellence EFQM offers a complex and diverse network of organizations that currently operate on the market a unique scale of criteria that makes it possible to compare each organization objectively [2,3].

The objective of article was to analyze the EFQM (European Foundation for Quality Management).

Another part was the analysis and complex presentation of the EFQM Model of Excellence. It is necessary to introduce and define each criterion in terms of leadership, people, strategy, partnership, and resources and processes, as well as each of the criteria found in the results area - the results - people, results - customers, results - the company and the key results [4,9].

MATERIAL AND METHODS

The EFQM excellence model was implemented in SMZ, a.s. Jelšava. The production program is aimed at the production of loose dead-burned magnesite refractory products, caustic magnesites and slag-forming additives and crude magnesites. The production of the organization is mainly for the steel industry, the production of fire materials, the chemical industry, agriculture and construction.

Sub-criteria - Leading - Leadership 10%

1a) assessing whether executives are at the same time leading figures and a model in applying the culture of excellence in SMZ, a.s. Jelšava,

1b) assessing whether executives are personally committed to ensuring the development, implementation, and continuous improvement of the organization's management system,

1c) assessing whether they engage in relationships with customers, partners and other

interest groups,

1d) assessing whether managers are motivating, promoting personal development and valuing workers,

1e) whether policy and strategy are consistently implemented in the organization.

Sub-criteria - Workers – People 10%

2a) whether human resources are planned, managed and developed,

2b) whether the knowledge and skills of workers are identified, developed and maintained,

2c) whether the staff of the organization are engaged and empowered to carry out individual processes,

2d) whether the workers and SMZ, a.s. Jelšava communicates and leads a dialogue together.

Sub-criteria - Policy and strategy 10%

3a) whether policy and strategy are based on current and future needs and expectations of interest groups in SMZ, a.s. Jelšava,

3b) whether the policy and strategy is based on information from surveys, education and application of other creative activities,

3c) whether the organization's policy and strategy is being developed, reviewed and innovated,

3d) whether policy and strategy is focused on all key processes,

3e) whether workers are appropriately remunerated and whether public forms of their recognition are used.

Sub-criteria - Partnership and resources 10%

4a) whether external partnerships are managed,

4b) whether the financial resources of SMZ, a.s. Jelšava are managed,

4c) whether the necessary care is devoted to buildings, facilities and materials,

4d) whether there are technological processes in the organization,

4e) whether information and knowledge are managed in the organization.

Sub-criteria - Processes 10%

5a) whether processes are systematically designed and managed,

5b) Whether processes are improved as needed with the use of innovation to fully satisfy and create added value for customers and other stakeholders,

5c) whether products and services are designed and developed based on customers' needs and expectations,

5d) how to realize the production, delivery and service of products and services in the organization SMZ, a.s. Jelšava,

5e) how the improved customer relationships are managed.

Sub-criteria - Results in relation to workers 10%

6a) what are employees' perceptions of the organization and whether they include an area of motivation, employee satisfaction in SMZ, a.s. Jelšava,

6b) what performance indicators are, in particular, in the area of competence transfer and whether they exist.

Sub-criteria - Results in relation to customers 15%

7a) whether or not there are customer perceptions of the organization, including the overall image of the organization - production, sales and service,

7b) whether there are other performance indicators in the SMZ, a.s. Jelšava that the organization uses to monitor, understand and improve customer perception.

Sub-criteria - Results in relation to the company 10%

8a) whether there are and what are the perceptions of the company, including, the issue of reducing the negative impact on the environment in SMZ, a.s. Jelšava,

8b) whether there are and what performance indicators are tracking changes in employment development, cooperation with foreign trade organizations, state authorities, etc.

Sub-criteria - Key outcomes of performance 15%

9a) what are the key outcomes achieved by SMZ, a.s. Jelšava - financial as well as non-financial,

9b) what are the key outcomes and performance indicators defined in relation to processes, external resources, assets, information, and so on.

Table 1 *Overall score of the ORGANIZATION (SMC Jelšava) self-assessment report*

1. Criteria - Assumptions											
Criteria number		1	%	2	%	3	%	4	%	5	%
Sub-criterion		1a		2a		3a		4a		5a	
Sub-criterion		1b		2b		3b		4b		5b	
Sub-criterion		1c		2c		3c		4c		5c	
Sub-criterion		1d		2d		3d		4d		5d	
Sub-criterion		1e				3e		4e		5e	
Total											
			÷ 5		÷ 4		÷ 5		÷ 5		÷ 5
Rating achieved											

Note:
the score obtained is the arithmetic mean of the percentages of the individual sub-criteria. If the applicant provides convincing reasons why one or more parts are not relevant to his organization, the average of only those values should be counted. To exclude ambiguities (with no result), the subcriteria may be recognized as irrelevant, denoted in the above table as "NR".

2. Criteria – Results																
	6			%	7			%	8			%	9			%
Sub-criterion	6a		x 0.75		7a		x 0.75		8a		x 0.50		9a		x 0.50	
Sub-criterion	6b		x 0.25		7b		x 0.25		8b		x 0.50		9b		x 0.50	
Rating achieved																

Using the EFQM model, the organization achieves a stable circle of subscription organizations with which it has maintained good business relations for several years [10].

RESULTS

Sub-criteria - Leading - Leadership 10%

Areas of improvement:

- strengthen the graphical presentation of the results in relation to employees,
- regular structured surveys with a steady form of presentation of the results,
- preparation of a new investment in the production of basic technologies,
- improving personal contacts with customers,
- direct support for communication in the supply chain,
- improving the achieved parameters of the machinery and equipment.

Proof:

1a) corporate newspaper, company policy,
1b) process model - process structures,
1c) Code of Ethics,
1d) controlled documentation,
1e) implemented policy.

Sub-criteria - Workers - People 10%

Strengths:

- Information and visualization of fulfilment of achieved parameters on the machinery.
- Stable team of employees
- Personal contact of leaders with employees

Areas of improvement:

- Employee motivation
- Improvement of the achieved machine parameters
- Improved communication at lower levels of control

Proof:

2a) Organizational documentation (guidelines, methodological guidelines),
2b) Satisfaction measurement questionnaire,
2c) Service Agreement,
2d) Reports from external testing audits.

Sub-criteria - Policy and strategy 10%

Strengths:

- Top technology and flexibility to respond to customer requirements,
- Close cooperation with suppliers and top buyers,
- Clearly formulated strategic goals,
- Regular monitoring of goals.

Areas of improvement:

- Analyzes of efficient production,
- Product innovation,
- To deepen and increase the focus on strategic partners - suppliers and consumers,
- Improve collaboration with colleges and universities.

Proof:

3a) enterprise information system,
3b) the SMZ, a.s. Jelšava web site,
3c) Quality certificates ISO 9001, ISO 14001, GMP + B2,
3d) evaluation of internal audits,
3e) company information systems.

Sub-criteria - Partnership and resources 10%

Strengths:

- Outstanding relationships both on the supplier side and on the customer side,

- Very good technical and technological equipment of the company,
- Continuous innovation of our product portfolio,
- Close cooperation supplier – customer,
- Excellent position within the region,
- Financial stability and high ability to pay.

Areas of improvement

- Need for investment in basic production,
- The stock of colours and thinners is too far away.

Proof:

4a) Advertising Agreement from. 183/2011, Loan agreement,

4b) Service Agreement,

4c) Business News, Chairman of the Board Directives,

4d) Director-General Directives,

4e) Decision of the SMZ Director, a.s. Jelšava, Methodical Instruction of the Director of SMZ, a.s. Jelsava.

Sub-Criteria - Processes 10%

Strengths:

- the company has defined and formulated processes,
- use of systematic collection of information for innovative activities,
- use of multiple ways of promoting products,
- product management based on non-anonymous customer contact,
- support for different forms of dialogue with customers.

Areas of improvement:

- wider use of the advanced versions of software to model processes,
- supplementing technical equipment in response to new technical possibilities,
- introduction of new forms of market research .

Proof:

5a) Process Model - Process Structures,

5b) Business Infoweb - Guidelines, Business Negotiation Documents,

5c) Website SMZ Jelšava a. s., corporate newspaper,

5d) certificates and service activities, complaint handling,

5e) a set of corporate technical standards, entries from external audits.

Sub-criteria - Results in relation to workers 10%

Strengths:

- Stabilized team of employees,
- Frequent, personal contact with employees,
- Revised data collection about performance parameters,
- Occupation of employees,
- Informing and showing the current state of fulfilment of stakeholder parameters,
- Introduced upgrade program.

Areas of improvement

- Interpersonal communication,
- Transfer information through middle management to lower levels,
- Detecting feedback via questionnaires.

Proof:

6a) questionnaire to measure the satisfaction of employees of SMZ, a.s. Jelšava, reports from external employee testing,

6b) KPI system, methodological instructions of the SMZ Director, a.s. Jelšava, improvement of processes and activities in society.

Sub-criteria - Customer-related results 15%

Strengths:

− Direct daily contact with decisive clients,

− Customer requirements are verified and immediately resolved with specialist departments,

− The customer then receives a qualified proposal to solve his problem,

− Customer relationships are systematically built and consolidated through joint projects and development cooperation and new projects,

− Ability to efficiently handle by optimization of order quantities.

Areas of improvement:

− Optimization of SCM in the use of production capacities and resource conservation,

− Increase professionalism in discovering causes and finding the essence of customer's problem,

− Better organization of work and use of technological knowledge to maintain and strengthen its position at customers,

Proof:

7a) analysis, statistics, surveys - all managed documentation,

7b) analysis, statistics, surveys - all managed documentation.

Sub-criteria - Results in relation to the company 10%

Strengths:

− compliance with, and observance of, applicable laws and standards for the protection of the environment, health and safety at work,

− support for entities in the region through the Foundation,

− the economic impact of the organization and its image,

− credibility of the organization.

Areas for improvement:

− Record awards and ,thank you letters,

− Record excursions made in the company,

− Analyze integrated marketing communications, - monitor media and publish it on the company's website,

− Organize events and projects aimed at the public, respectively. with the participation of the wider public.

Proof:

8a) Corporate newspapers, print media

8b) Management report of SMZ, a.s. Jelšava, 2012, 2013, 2014, 2015

Sub-criteria - Key performance outcomes 15%

Strengths:

− A modern competitive company,

− A leader in the Slovak market and a major converter in Central and Eastern Europe,

− Market standing - Stable, mature transnational clientele both as exporter and importer,

− Customer Priority, Shareholder, Employee, Largest Employer in the Region.

Areas of improvement:

− Improving performance,

− Expansion of the product and service portfolio,

− Customer orientation,

− Raising expertise.

Proof:

9a) a comprehensive business plan,

9b) KPI - tracking key performance indicators.

Table 2 *Overall Score ORGANIZATION (SMC Jelšava) self-assessment report*

1. Criteria - Assumptions

Criteria number		1	%	2	%	3	%	4	%	5	%
Sub-criterion		1a	99	2a	90	3a	96	4a	94	5a	94
Sub-criterion		1b	95	2b	95	3b	95	4b	89	5b	90
Sub-criterion		1c	97	2c	96	3c	95	4c	92	5c	90
Sub-criterion		1d	86	2d	86	3d	98	4d	96	5d	96
Sub-criterion		1e	86			3e	95	4e	95	5e	97
Total			463		367		479		466		467
			÷ 5		÷ 4		÷ 5		÷ 5		÷ 5
Rating achieved			**92.6**		**91.7**		**95.8**		**93.2**		**93.4**

Note:
the score obtained is the arithmetic mean of the percentages of the individual sub-criteria. If the applicant provides convincing reasons why one or more parts are not relevant to his organization, the average of only those values should be counted. To exclude ambiguities (with no result), the subcriteria may be recognized as irrelevant denoted in the above table as "NR".

2. Criteria - Results

	6			%	7			%	8			%	9			%
Sub-criterion	6a	52	x 0.75	39	7a	52	x 0.75	39	8a	88	x 0.5	44	9a	86	x 0.5	43
Sub-criterion	6b	34	x 0.25	8.5	7b	82	x 0.25	20.5	8b	88	x 0.5	44	9b	74	x 0.5	37
Rating achieved				**47.5**				**59.5**				**88**				**80**

3. Total points

Criteria	Rating achieved	Coefficient	Final rating
1 Leading / Leadership	92.6	x 1.0	92.6
2 Workers / People	91.7	x 1.0	91.7
3 Policy and strategy	95.8	x 1.0	95.8
4 Partnership and resources	93.2	x 1.0	93.2
5 Processes, products and services	93.4	x 1.0	93.4
6 Results in relation to customers	47.5	x 1.5	71.25
7 Results in relation to workers	59.5	x 1.0	59.5
8 Results in relation to the company	88	x 1.0	88
9 Key results	80	x 1.5	120
Total score points			**805.4**

***Table 3** Average Rating of the EFQM Excellence Model Criteria*

Criteria	Max points	Self-assessment of the organization SMZ a. s. Jelšava	Evaluation of UNMS SR National SR Prize for Quality
Leading / Leadership	100	92.6	48.7
Workers / People	100	91.7	65
Politics and Strategy	100	95.8	65.7
Partnership and resources	100	93.2	58.5
Processes, products, services	100	93.4	64.5
Results in relation to workers	100	71.25	50
Results in relation to customers	150	59.5	46
Results in relation to the company	100	88	59
Key results	150	120	98
	1000	**805.4**	**555.4**

CONCLUSION

Implementation of comprehensive quality management must be planned, this is a long-term change of processes, thinking of people. Without a clear long-term plan in the organization, quality cannot be improved. It is important to systematically plan the future of the organization. The necessity of introducing comprehensive quality management is a prerequisite for a qualified deal with this issue. Procedures for the implementation of comprehensive quality management are described in various scientific publications dealing with this issue. Since comprehensive quality management is mostly aimed to manage change, focusing on a comprehensive understanding of quality, involving all employees, it must be seen as a management model that will be embedded in continuous development and sustained improvement.

It is important to recognize that comprehensive quality management is the work of the entire management and all employees. The management decision for comprehensive quality management is the beginning of profound changes in the culture of the organization.

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Monitoring the Manufacturing Process in the Selected Organization

Pavol Findura, Maros Korenko, Slawomir Kocira, Marek Gugala

Abstract: *The goal of the article was to determine the capability of the manufacturing process of turning component „the turbine hub." The subject of the practical part is to measure 4 specific parameters on 100 collected samples. Measured results have been evaluated according to the specified methodology. It was being determined whether the variability and average of the process are in the statistically mastered state. The second parameter of the process did not complied with this requirement in three cases. Identified results of each four parameters are: first: P_p=1.803, P_{pk}=1.886. The process is capable when $P_p / P_{pk} \geq 1.67$. Production process was fully capable.*

Keywords: *quality management, production process, monitoring the capability of the manufacturing process, process capability index.*

INTRODUCTION

At present, the world market is full of organizations that seek to attract and, above all, maintain customers. Their goal must not only be the production of any kind of products. Their products must have a high level of quality so they can take on a potential customer because today's customers can choose what they buy and therefore it's their right to be demanding [1,6,13]. Therefore, it is necessary for the organization to constantly strive to be competitive. The right way is to introduce statistical control methods into the processes. One of these methods is to determine the capability of the production process. The ISO 9001 standard even requires and specifies the requirements for the quality management system and includes methods that help keep the production process in a stacked state. When these methods are applied correctly in practice, the quality of the process increases as well as the product quality and customer satisfaction [7,9].

Nowadays, it is essential for the organization to ensure that its products exhibit the highest possible quality. It depends on its survival in the market where there are a number of other competitive organizations. In this regard, one of the important tools for the organization is the use of statistical methods to control processes, which contribute to process, improvement, and make the final products meet the required quality [2,5,8]. The aim of the article was to apply statistical methods in quality management. In this paper, we investigated the short-term capability of the turbine cartridge turning process. This component is used in a four-speed hydrodynamic torque converter [4,16].

MATERIAL AND METHODS

In the given organization, we collected 5 parts of the components during 20 shifts. Sampling was done by random selection. About 100 samples were collected. On each of them, we measured the specified parameters and wrote down in the table, from which we subsequently produced the measured value card [17,18,20]. The measured data was divided into 20 subgroups of 5 measurements, which were processed according to the formulas given in the methodology [1,19,23]. The necessary values were recorded in the X-card and R card, which helped to determine whether the process is in a stacked state. If proven, we continued to investigate the process capability [10,22].

Evaluation of measured values

− *average range in subgroups*

$$\overline{X}_i = \frac{1}{n}\sum_{j=1}^{n} X_{ij} \qquad (1)$$

i= 1,2,... k j = 1,2, ... n,
X_{ij} – measured value in i- subgroups
j –serial number of measured value in i- subgroups
k –number of subgroups
n –file size
− *interval in subgroups:*

$$R_i = MAX(X_{ij}) - MIN(X_{ij}) \tag{2}$$

i = 1,2,...k and j = 1,2,... n,
$MAX(X_{ij})$ a $MIN(X_{ij})$ maximum and minimum *measured value in i- subgroups*
− *calculation of equivalent span* $(\overline{R})$ *and average process* $(\overline{\overline{X}})$*:*

$$\overline{R} = \frac{1}{k}\sum_{i=1}^{k} R_i \tag{3}$$

− *average process:*

$$\overline{\overline{X}} = \frac{1}{k}\sum_{i=1}^{k} \overline{X}_i \tag{4}$$

$R_i, \overline{X}_i$ interval and averages in i- subgroups (i = 1,2,....k).
$\overline{R}$, $\overline{\overline{X}}$ in regulations diagrams produce central lines (CL).
− *calculation Specification limit:*

$$UCL_R = D_4.\overline{R} \tag{5}$$

$$LCL_R = D_3.\overline{R} \tag{6}$$

$$UCL_{\overline{X}} = \overline{\overline{X}} + A_2.\overline{R} \tag{7}$$

$$LCL_{\overline{X}} = \overline{\overline{X}} - A_2.\overline{R} \tag{8}$$

D_4, D_3, A_2: constant factor which is being changed by range of subgroup, in our case for 5 measured   rates in a choice $D_4 = 2.114, D_3 = 0, A_2 = 0.577$

Qualification of a process

Before counting of indicators of process qualification, a standard deviation should be estimated:

$$\hat{\sigma} = \frac{\overline{R}}{d_2} \tag{9}$$

$\overline{R}$ - average range in subgroups
d_2 - constant factor which is being changed by range of subgroup, in our case for 5 measured   rates in a choice **d_2=2.326**
− *capability process index* C_p *:*

$$C_p = \frac{USL - LSL}{6\hat{\sigma}} \tag{10}$$

USL – Upper Specification limit
LSL – Lower Specification limit

− *corrected Capability process index* C_{PK} :

$$C_{pk} = \frac{USL - \overline{\overline{X}}}{6\hat{\sigma}} \tag{11}$$

$$C_{pk} = \frac{\overline{\overline{X}} - LSL}{6\hat{\sigma}} \tag{12}$$

Component characteristics

Turbine charge is a component used in most cars and light and heavy trucks. It is located between the brake drums or wheels and the drive axle. On the axle side, it is mounted from the chassis to the holding console.

This component is part of a four-speed hydrodynamic torque converter. It is supplied as a semi-finished product that has a deformed outer and inner diameter [7].

Fig. 1 Component before trimming

Fig. 2 Component after trimming

Examined parameters

− 5.7 mm ± 0.05 mm lenght parameter, important feature.

Important feature – this dimension must be manufactured as precisely as possible, or it may cause problems in the future assembly of the component (in conjunction with the other components in the system). Labeling of the important features is determined after the design has been done in the production / assembly drawing, and the character is given in a rounded frame [11,12].

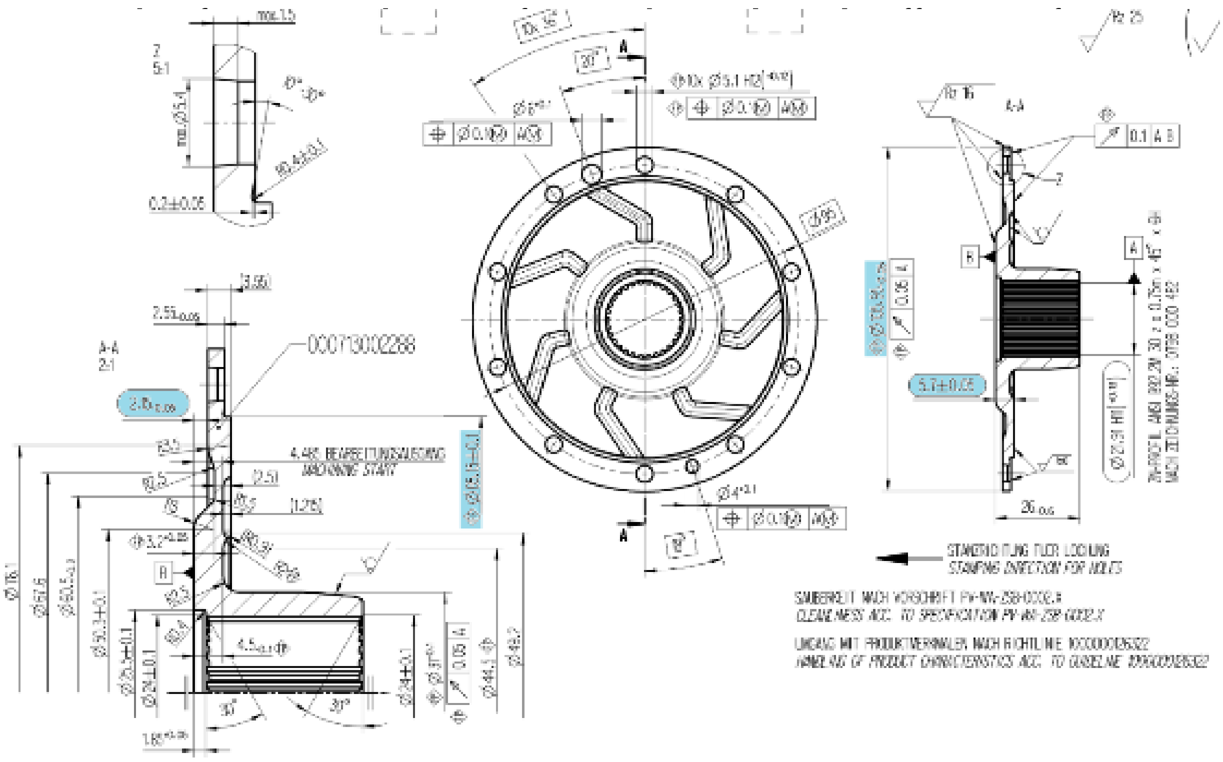

Fig. 3 The drawing of the component and the examined parameters

From a technological point of view, trimming is considered as the basic machining method. It is versatile, it can be machined by various external and internal surfaces.

Gauges

Examined component dimensions are controlled objectively by means of gauges (fig. 4). In these cases, a comparative measurement is performed using numerical deviations, in which the deviations are directly measured from the set dimension. It is determined if the dimensions are within the prescribed limits, which guarantee the assembly of the components without further modifications [7,15].

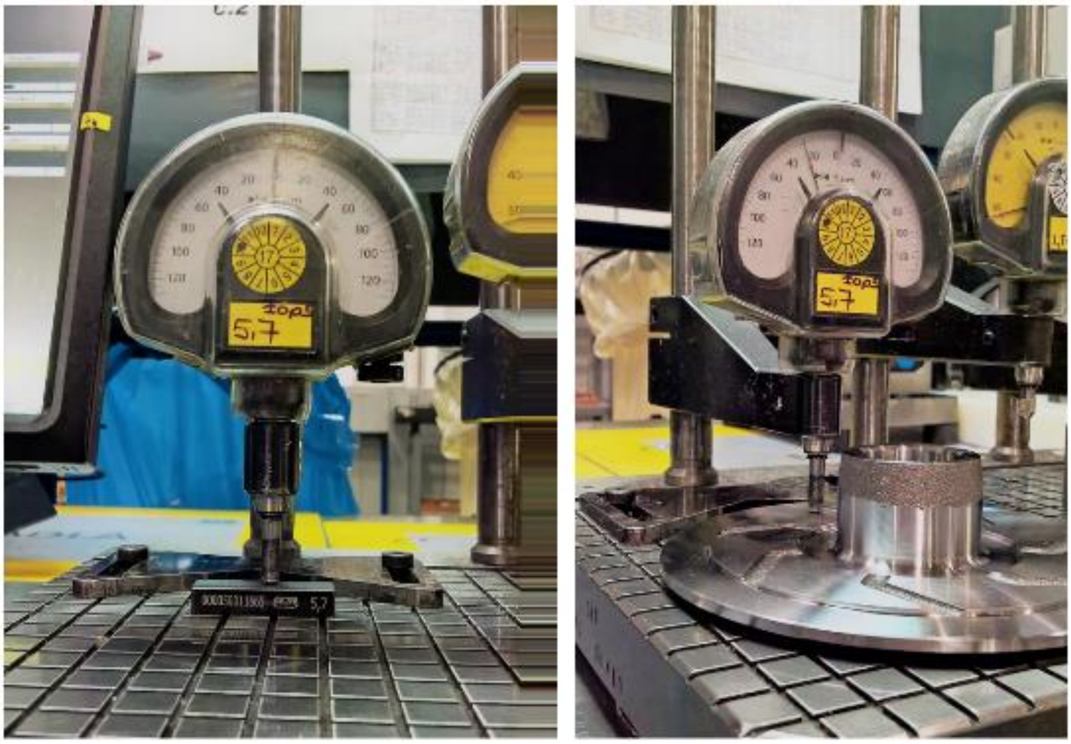

Fig. 4 Gauger for the dimension 5.7 mm ± 0.05mm

Evaluation of measured values

From each parameter, 100 values were collected, which were processed into 20 subgroups with 5 values. The collected data is graphically displayed in the measured values tab [7,14,21].

Determination of limit values

We calculated the mean value of the feature in the subgroup $\overline{X_i}$ the span in the subgroup R_i and the process diameter $\overline{\overline{X}}$ and the average span $\overline{R}$.

$$UCL_{\overline{X}} = 5.712 + 0.577 \ x \ 0.0182 = 5.723 \tag{13}$$

$$LCL_{\overline{X}} = 5.712 - 0.577 \ x \ 0.0182 = 5.702 \tag{14}$$

$$UCL_R = 2.114 \ x \ 0.0182 = 0.0386 \tag{15}$$

$$LCL_R = 0 \ x \ 0.0182 = 0 \tag{16}$$

The values were processed into $\overline{X}$ card and R card. They are analyzed individually. In the $\overline{X}$- card there are six points out of the regulatory limits. This process parameter is statistically unmanageable. There is no point in the R card outside of the regulatory limit. The process parameter is in a stacked state.

Parameter 5.7 mm ± 0.05mm

Tab. 1 Table of measured values divided into 5 subgroups for parameter 5.7 mm ± 0.05mm

5.7 mm ±0,05mm							
P.č.	X_1	X_2	X_3	X_4	X_5	$\overline{X_i}$	R_i
1	5.710	5.705	5.710	5.715	5.710	5.710	0.010
2	5.705	5.725	5.710	5.695	5.700	5.707	0.030
3	5.710	5.730	5.730	5.715	5.715	5.720	0.020
4	5.705	5.710	5.695	5.690	5.695	5.699	0.020
5	5.690	5.685	5.720	5.720	5.705	5.704	0.035
6	5.685	5.680	5.710	5.695	5.695	5.693	0.030
7	5.720	5.715	5.710	5.710	5.715	5.714	0.010
8	5.720	5.725	5.725	5.710	5.710	5.718	0.015
9	5.730	5.730	5.730	5.730	5.735	5.731	0.005
10	5.705	5.710	5.715	5.715	5.715	5.712	0.010
11	5.710	5.710	5.695	5.690	5.695	5.700	0.020
12	5.720	5.720	5.720	5.730	5.730	5.724	0.010
13	5.710	5.710	5.705	5.710	5.695	5.706	0.015
14	5.705	5.710	5.695	5.710	5.710	5.706	0.015
15	5.715	5.725	5.710	5.705	5.725	5.716	0.020
16	5.725	5.730	5.730	5.725	5.730	5.728	0.005
17	5.710	5.725	5.710	5.705	5.715	5.713	0.020
18	5.720	5.730	5.730	5.710	5.710	5.720	0.020
19	5.705	5.720	5.720	5.725	5.710	5.716	0.020
20	5.715	5.710	5.695	5.685	5.720	5.705	0.035
						$\overline{\overline{x}} = 5.712$	$\overline{R} = 0.0182$

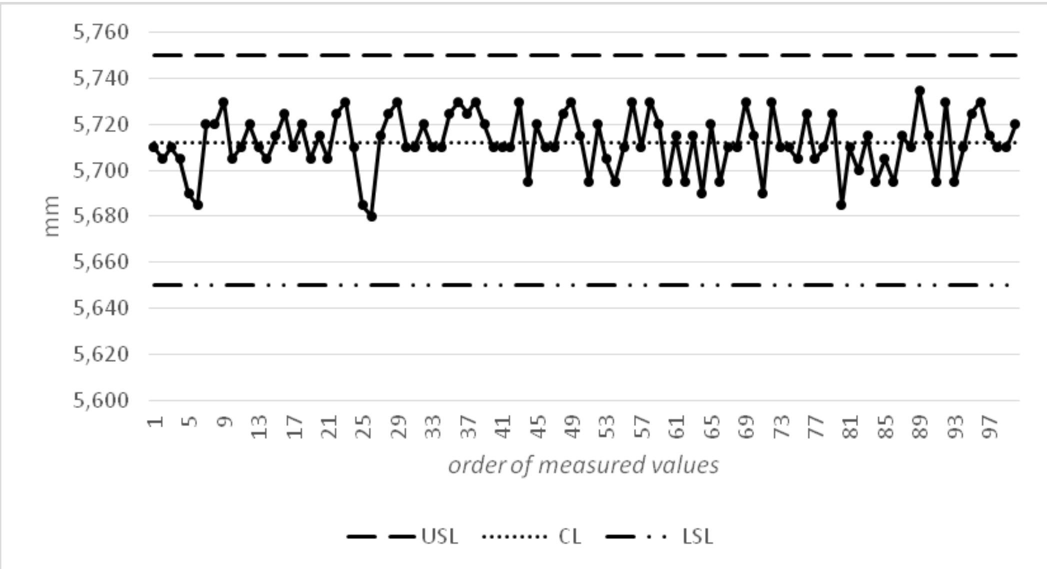

Fig. 5 The measured value card for the parameter 5.7 mm ± 0.05mm

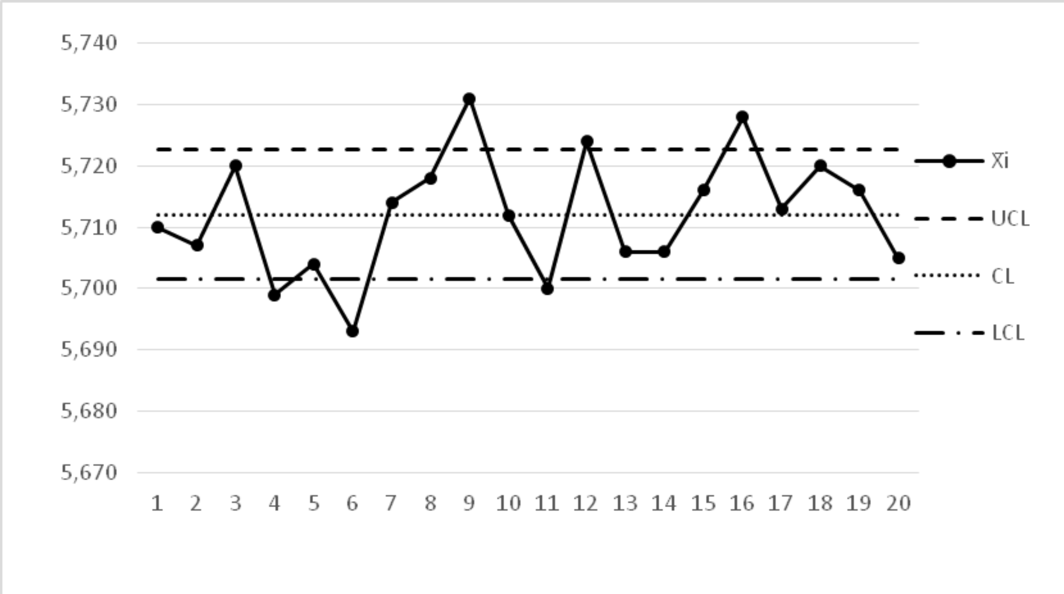

Fig. 6 X – card for parameter 5.7 mm ± 0.05mm

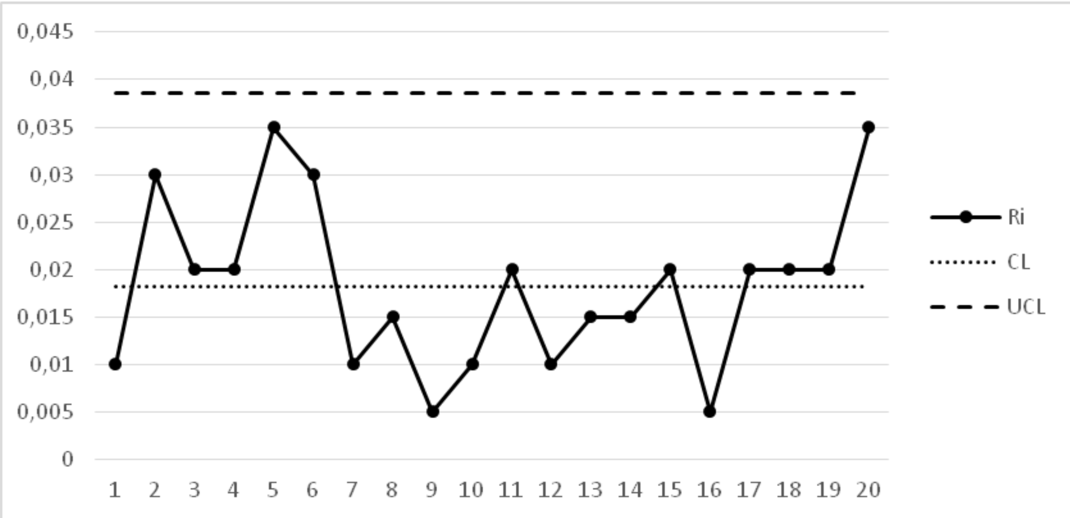

Fig. 7 R – card for parameter 5,7 mm ± 0,05mm

Process capability

Before calculating process capability indices, it is necessary to determine the standard deviation, with the constant d_2 = 2.326

We have calculated the Pp and Ppk indices, taking the lower value in the evaluation into account.

$$\hat{\sigma} = \frac{0.0182}{2.326} = 0.00785 \tag{17}$$

$$P_p = \frac{0.1}{6\ x\ 0.00785} = 2.124 \tag{18}$$

$$P_{pk} = \frac{5.750 - 5.712}{3 \ x \ 0.00785} = 1.610 \tag{19}$$

$$P_{pk} = \frac{5.712 - 5.650}{3 \ x \ 0.00785} = 2.638 \tag{20}$$

This process is conditionally eligible.

CONCLUSION

If an organization is interested in being able to compete with other organizations at present but mostly in the future, it needs to take certain measures. Their capability must be periodically inspected to avoid unwanted disturbances and if they occur to be quickly identified and removed. Therefore, it is appropriate to introduce statistical methods for process control.

In the article we applied statistical methods in the turbine turning process. The goal was to examine the short term capability of this process using the P_p a $P_{pk.}$indices by means of the parameters of this component. The necessary values were recorded in the X-card and the R-card, from which we determined if the process diameter and the process variability are in a statistically controlled state. Variability was statistically mastered in each process. The process average did not meet this requirement. The manufacturing process has proved to be conditionally capable. From the acquired findings about these processes, it may be concluded that corrective actions need to be taken to eliminate undesirable effects, that means stabilize processes. An appropriate measure already carried out by the organization is the input control of the semi-product when taking on from the supplier by means of a check sheet.

Among the causes that influence the process, the parameter settings in the machining process can be considered. To improve the process, for example, it is advisable to use cutting blades with the longest possible life. They will ensure the most accurate dimension of the component. During the process, it is also important to use a suitable coolant to monitor the machining temperature.

In addition, it is necessary to regularly check the condition of the lathe and take care of the correct maintenance method. It is therefore important to train staff involved in the inspection, maintenance and operation of the machine.

The results of the process could also be adversely affected in the component parameter measurement phase. The causes that can affect the measuring area include the ambient temperature at which the component parameters were measured. When using high precision instruments, changing ambient temperatures may cause measurement deviations. Therefore, it is necessary to ensure conditions for measurement at a suitable ambient temperature without any deflections.

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Municipal Waste Utilization by Automatic Sorting Technology

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Abstract: *The waste could be described as an unnecessary, but not unusable, by-product of human activity. From the point of view of a common human being, the most significant type of waste is municipal waste. This waste is produced by all of us regardless of our social status, wealth or education. It is created during ordinary activities, at home, at work or at school, and it is one of the few kinds of waste which production we can limit by our own responsible approach. The aim of the accession was to describe the measurement of the separation cleanliness. The measured type of waste was iron waste incorporated in plastic waste - PET + drugstore (PP / PE).*

Keywords: *Separation, measurement, waste, production, sorting line*

INTRODUCTION

In total 9.5 million tons of waste is generated per year in Slovakia. Industrial waste is traditionally the largest. Municipal waste accounts for approximately 1.7 million annually, and up to 75% of this wastes end in landfills. Compared to the EU countries, Slovakia belongs to the countries with the lowest annual municipal waste production per capita. The average Slovak produces an average of 327 kg of municipal waste per year but segregates only 23 kg of waste (plastic, glass, paper and metal) compared to EU countries it is very low (the EU average is 111 kg). Lower production of municipal waste per capita is only in Poland, Estonia and Romania. Mostly, about a third of all waste is generated in industrial production (an average of 2.7 million tons per year), construction (an average of 1.67 million tons per year), electricity and gas supply (937-thousand tons) and supply and water purification (747-thousand tons).

The long-term negative trend of waste management in Slovakia is their disposal in landfills. The amount of waste dumped to landfills has increased from 2010 up to now to five million tons, which means that more than half of all waste produced in Slovakia is dumped to landfills. Only 25 percent in average was recycled in the monitored year 2013 to the present. Without an energy utilization, an average of 55-thousand tons of waste is disposed by combustion annually, with only three percent of the energy utilized, which is about 300 thousand tons of waste per year. The high level of disposal of waste in landfills is also the biggest danger in municipal waste management.

Precaution to reduce the volume of municipal waste in landfills

There are many simple solutions to reduce the amount of usable waste in landfills, which include the simplest forms, from decreasing the human consumption to waste sorting, and setting the legislative framework for the state, resp. responsible authorities within the EU with the solution of waste purchase and use as a secondary raw material, which is partly happening but with very low quality and low volume.

Taking into account the fact with respect of ever-increasing consumption of material inputs related to increasing production of commodities to meet the demand, the artificial reduction of municipal waste production per human being or per production company (the producer of waste) is currently unrealistic, the possibilities of reducing and storing is somewhere else.

Slovakia, as an EU Member State, must subsequently take measures to promote recycling itself and to ensure efficient sorting of municipal waste by pre-separation and collection at the centers as one of the easiest and cheapest forms of the initial phase of its disposal. At present, the SR has an obligation for the municipality to introduce and ensure the implementation of classified collection of municipal waste for paper, plastics, metals, glass

and biodegradable municipal waste.

In order to meet the recycling target, the level of sorted harvest must be at least 150-170 kg per capita, which will be very difficult to meet by 2020.

It would be helpful to efficiently separate into the specified species, with the highest possible purity and exceed quality, so it can subsequently be used as a potential feedstock for the industry (secondary raw material, fuel, etc.) in the most efficient way. At this time, separating (sorting) centers according to the volume of waste processed are either manual or automatic.

Manual Sorting Centers

The manual sorting (separating or recycling) centers are composed of the necessary number of workers and the minimum amount of technological equipment needed (conveyors, storage cubicles, or pre-sorting sieves, to separate the oversized or undersized fractions) for the separation of visually identifiable waste - by color (PET bottles, oversized plastics, visible fractions such as rubber, glass, etc.) from other parts of the waste. However, they have limited sorting parameters related to the "visibility" factor as well as the quantity of the sorted waste. In general, and according to available data from existing plants of such centers, the worker is able to dispose approximately 30-40 kg of distinguishable waste, which in today's waste production and its need to sort out is a poor solution.

Automatic sorting workstations

Sorting more waste according to the color spectrum or the chemical composition of the waste is currently possible only with an automatic sorting system composed of several machine-process equipment which is controlled by a control system with its own imaging unit to control the process flow of waste treatment based on functional conditions at the same time with a view to ensuring the main safety features.

The composition of such a sorting line is normally assembled with technological equipment such as:

- unpacking device (if the raw material comes in pressed packages),
- transport systems (conveyors, hopper-dump parts - transport and shipment of waste stream / flow),
- sieves (separation of over-limiting or subliminal parts of waste for further processing),
- vibration systems (uniform distribution of waste before automatic sorting),
- automatic sorting devices (so-called NIR / VIS systems),
- collection boxes with removals,
- pressing equipment (hydraulic vertical presses, pressing containers).

Automatic sorting can be set up to a waste processing rate of 10 t / h on a single separation device. In the case of larger flows, the supply channel can be divided and additional separation devices can be added. However, such a speed is several times higher than manual sorting and is sufficient for complete waste treatment. Just for comparison, work on 1 automatic sorting machine in a 3-shift operation will generate a stream of nearly 90,000 tons of waste, which is the production of a 500,000 city.

The cleanness of the automatic separation is 95%, manual separation is used to achieve 100% purity.

MATERIAL AND METHODS

In the month of 12/01/2018 in area of company VÚMZ SK, s.r.o, we had the NIR Finder optical sorting machine, a metal waste machine, 1200 table width, belt speed at 3.6 m / s, optical scanners from Tomra Sorting,s.r.o. and measured one of the main sorting parameters - cleanliness of sorting. The type of waste we measured was iron waste incorporated in plastic waste - PET + drugstore (PP / PE).

Fig. 1 Autosort automatic sorting system by Tomra

The conditions for separating of the sorted material were not ideal since the machine was placed after its production only on the ground and the distribution of the two waste streams (sorted and residual - the REST) was not standard in the installation as it is in the installed technological line (NIR are placed by default above the removal conveyors with dispensing portions that collect all the firing parts).

Tracked parameters during measurement

- • Noise
- • Vibration
- • Sorting clarity along with contamination in the sorted portion of the waste stream

Number of repeated measurements: 3

Speed steps: 5 (40% / 55% / 70% / 85% / 100%)

Volume and weight of sorted materials:

- PET / drugstore: 2.1 kg
- Metal material: 3.0 kg
- Condition Correction: 20%

Functional automatic sorting system

In present several systems of mechanical separation are currently used, depending on the form and character of materials (flotation, air separation, camera systems, laser, X Ray, etc), but the most widely used municipal waste sorting system is a method of optical separation of waste based on artificial preexposure of waste stream, its subsequent scanning by infrared (IR) rays and pneumatic firing of the detected materials to a designated position (collection chamber with a convex conveyor). This system of scanning, evaluating and subsequently firing the sorted waste into the target spaces is an indispensable way of automatic sorting with such high purity and speed in present time.

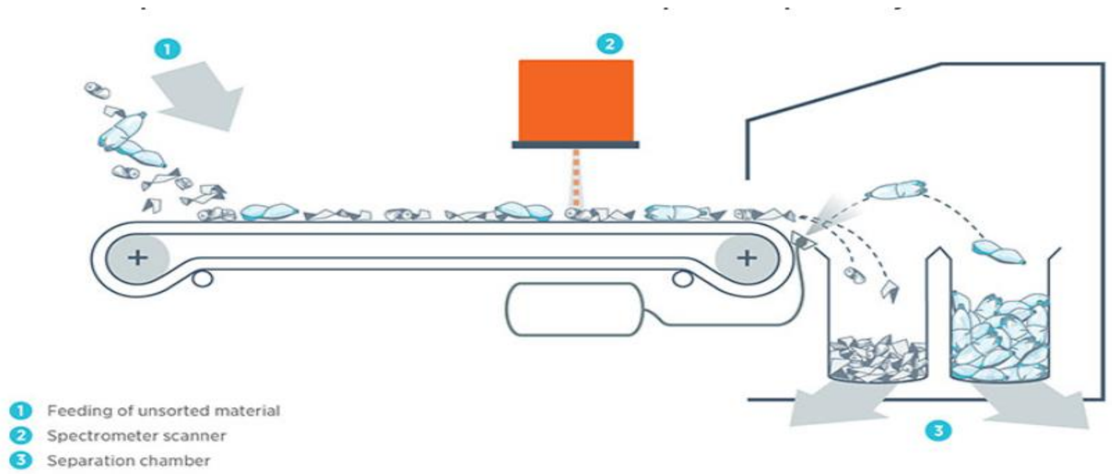


Fig. 2 The principle of the optical sorting

The principle of NIR operation / principle

The input material is evenly fed to the acceleration conveyor belt where it is detected by the AUTOSORT scanner unit and the optional EM sensor scanning the entire width of the belt in the sorting line. If one sensor detects the sorting material, it instructs the control cabinet to start blowing through the right valves of the valve block at the end of the acceleration conveyor belt. The sorted material is air-drawn through the separating cylinder inside the expansion chamber, "Section of the expansion chamber showing the partition wall". The rest will fall on the lower conveyor belt or the hopper.

VBPS is a mechanical superstructure of the valve block. Allows the valve block (s) to be diverted from the conveyor belt to allow easy cleaning and servicing. The valve block moves with the force of compressed air. The VBPS air pressure regulator unit is connected to the main air supply for the AUTOSORT. The VBPS control cabinet provides two terminals with different pressures.

The VBPS control cabinet includes all electrical parts and a control valve for filling one or the other air cylinder chamber.

RESULTS

The measurements showed the dependence of the purity, noise and vibration levels monitored on the speed so that the best value was achieved at 55% and 100% of revolutions.

However, during standard operation at 100% of revolutions are usually transported approximately 2 times higher material (waste) amounts - the flow - of processed waste stream, the result clearly indicates, that best sorting is set at a speed close to the maximum. This is happening in praxis and the technicians of the sorting machine set the units to the highest possible operating speed of the conveyor belt for obtaining best scanning and sorting results.

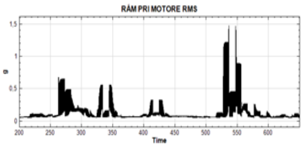
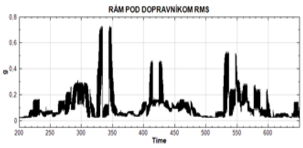
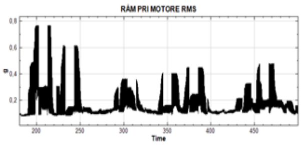
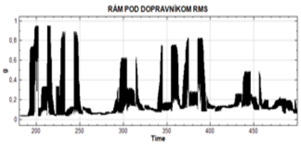
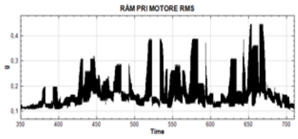
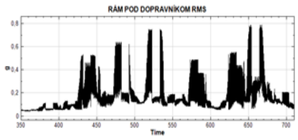
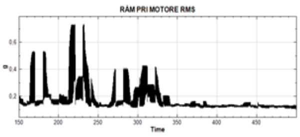
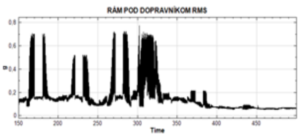
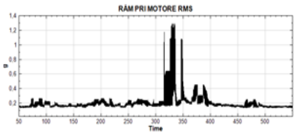
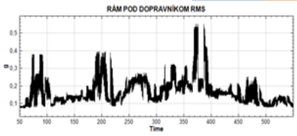
Otáčky :				OPTICKÉ TRIEDENIE				HLUČNOSŤ				
	otáčky (m/s)			netriedený tok		triedený tok						
				Fe	PET	Fe	PET	LA	LACq	LAmax	LCpeak	
		meranie 1		0,91	1,00	1,95	1,09					
40%	1,44	korekcia Fe k množstvu	1,05	0,95	1,00	2,05	1,09					
		korekcia k ost.vplyvom		**0,54**	1,00	**2,46**	1,09					
		účinnosť separácie / kontaminácia				82%	52%	67,20	88,20	98,10	111,60	dB
	vibrácie											
								LA	LACq	LAmax	LCpeak	
55%	1,98	**meranie 2**		0,95	1,13	1,77	0,96					
		korekcia Fe	1,10	1,05	1,13	1,95	0,96					
		korekcia k ost.vplyvom		**0,66**	1,13	**2,34**	0,96					
						78%	46%	70,10	93,00	98,90	112,20	dB
	vibrácie											
								LA	LACq	LAmax	LCpeak	
		meranie 3		1,57	0,94	1,17	1,15					
70%	2,52	korekcia Fe	1,09	1,72	0,94	1,28	1,15					
		korekcia k ost.vplyvom		**1,46**	0,94	**1,54**	1,15					
						51%	55%	66,00	92,00	99,70	111,80	dB
	vibrácie											
								LA	LACq	LAmax	LCpeak	
85%	3,06	**meranie 4**		1,25	0,99	1,55	1,10					
		korekcia Fe	1,07	1,34	0,99	1,66	1,10					
		korekcia k ost.vplyvom		**1,01**	0,99	**1,99**	1,10					
						66%	53%	72,30	96,00	101,90	113,10	dB
	vibrácie											
								LA	LACq	LAmax	LCpeak	
100%	3,60	**meranie 5**		0,98	1,06	1,82	1,03					
		korekcia Fe	1,07	1,05	1,06	1,95	1,03					
		korekcia k ost.vplyvom		**0,66**	1,06	**2,34**	1,03					
						78%	49%	71,50	96,00	102,80	113,50	dB
	vibrácie											

Fig. 3 Measurement results of selected sorting parameters on NIR / Finder

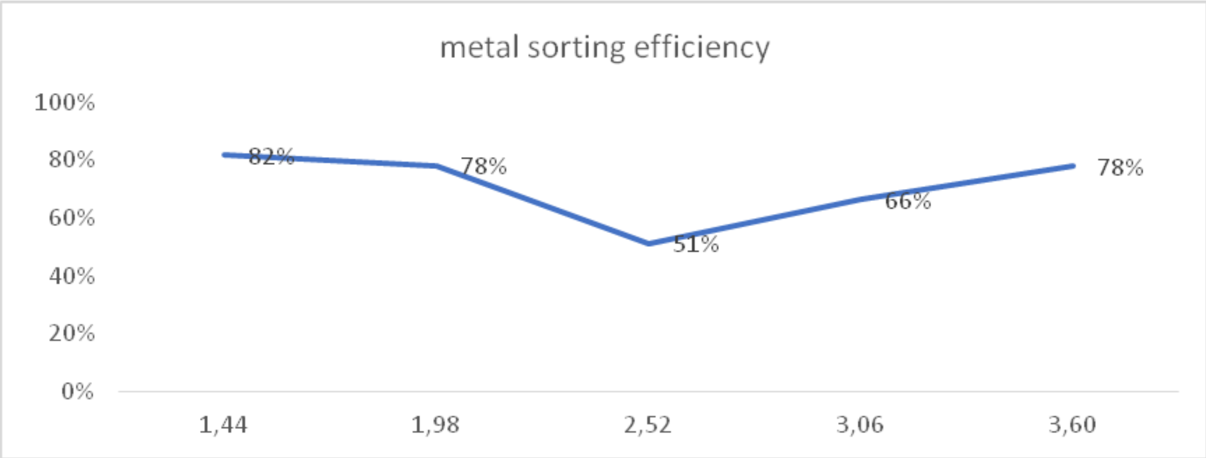


Fig. 4 Graphical representation of outputs / results gain from the measurements

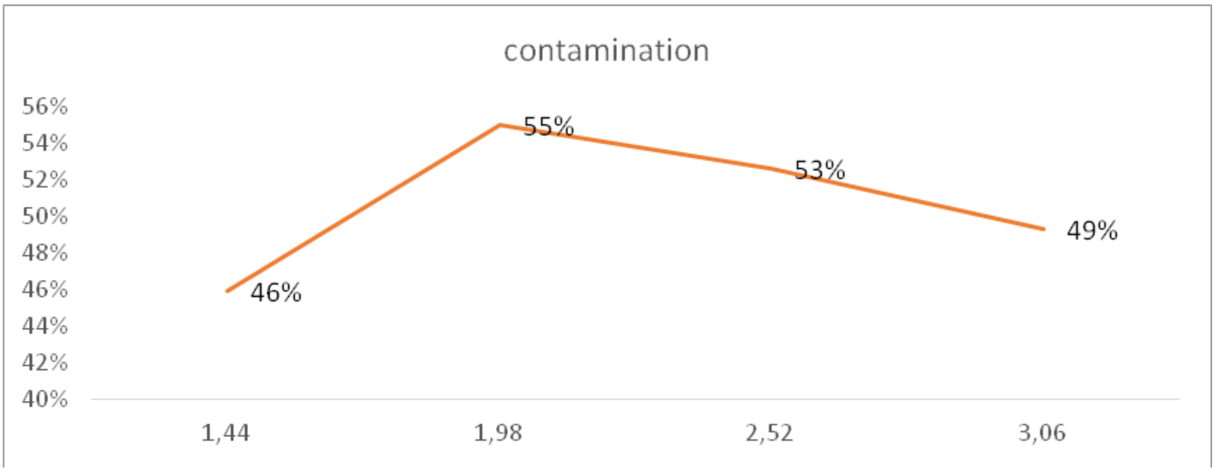


Fig. 5 Graphical representation of outputs / results gain from the measurements

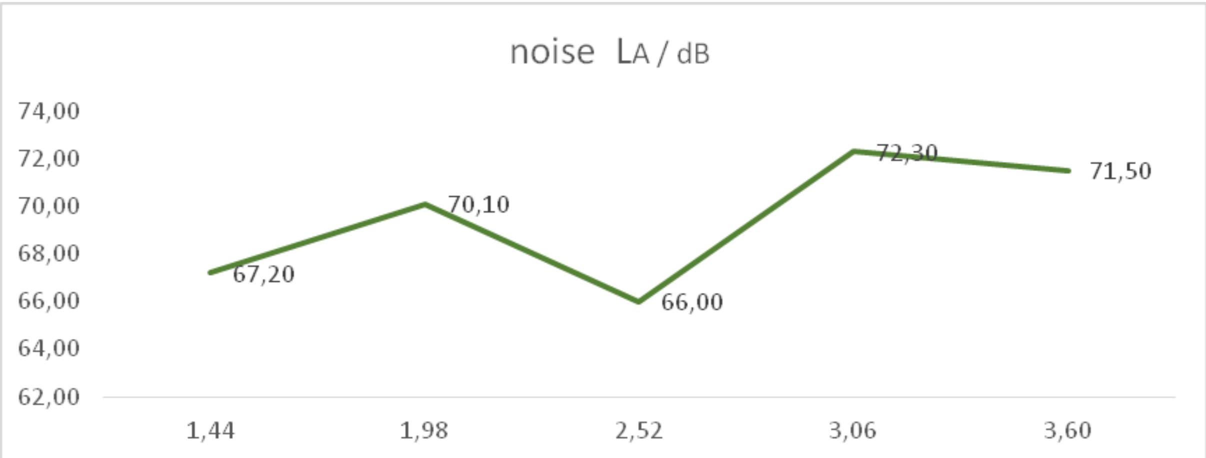


Fig. 5 Graphical representation of outputs / results gain from the measurements

CONCLUSION

In the submitted report, we looked at the condition of municipal waste management, currently pointing to the role of the responsible authorities and the preparation of Slovak legislation, respectively EU directives.

The condition of municipal waste management in Slovakia is quite unfavorable compared to other neighbor or highly-developed countries . Most of the waste instead of being used as a recoverable item for the needs of industry as a secondary raw material or in energy as a fuel (TAP) ends mostly in landfills.

The report describes possibilities of municipal waste evaluation aiming not to abolish, but reduce volume of the landfilled waste to a possible minimum. The most promising is its disposal by sorting. For the volume of waste processed in the best investment CAPEX / operating costs OPEX ratio against to the volume of technologically processed waste flow, automatic sorting appears as the best solution. As an example is introduced the most promising system of classification using IR-based optical heads, followed by evaluation and pneumatic blasting into designated channels for further conveying and processing.

The report presents the measurements made on the Finder optical sorting machine produced by the Slovak technological and production company VÚMZ SK, registered in Nitra Sorters were equipped with optical heads supplied by Tomra Sorting Solutions / Germany.

Received measurements showed the direct influence of the set revolutions – the speed of the input conveyor , so that the best figures were achieved at the mid and maximum speeds. However, for the parameter of the conveyed and processed stream, the main parameter is influenced by the volume of the treated waste flow.

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